Contributions to Sustainable Urban Transport: Decision Support for Alternative Mobility and Logistics Concepts

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I. Abstract

Increasing transport activities in cities are a substantial driver for congestion and pollution, influencing urban populations' health and quality of life. These effects are consequences of ongoing urbanization in combination with rising individual demand for mobility, goods, and services. With the goal of increased environmental sustainability in urban areas, city authorities and politics aim for reduced traffic and minimized transport emissions.

To support more efficient and sustainable urban transport, this cumulative dissertation focuses on alternative transport concepts. For this purpose, scientific methods and models of the interdisciplinary information systems domain combined with elements of operations research, transportation, and logistics are developed and investigated in multiple research contributions. Different transport concepts are examined in terms of optimization and acceptance to provide decision support for relevant stakeholders. In more detail, the overarching topic of urban transport in this dissertation is divided into the complexes *urban mobility* (part A) in terms of passenger transport and *urban logistics* (part B) with a focus on the delivery of goods and services. Within part A, approaches to carsharing optimization are presented at various planning levels. Furthermore, the user acceptance of ridepooling is investigated. Part B outlines several optimization models for alternative urban parcel and e-grocery delivery concepts by proposing different network structures and transport vehicles. Conducted surveys on intentional use of urban logistics concepts give valuable hints to providers and decision makers.

The introduced approaches with their corresponding results provide target-oriented support to facilitate decision making based on quantitative data. Due to the continuous growth of urban transport, the relevance of decision support in this regard, but also the understanding of the key drivers for people to use certain services will further increase in the future. By providing decision support for urban mobility as well as urban logistics concepts, this dissertation contributes to enhanced economic, social, and environmental sustainability in urban areas.

Keywords: Information Systems Research, Decision Support, Operations Research, Acceptance Research, Urban Transport, Urban Mobility, Urban Logistics, Sustainability.

Abstrakt

Zunehmende Verkehrsaktivitäten in Städten verursachen Staus und Umweltverschmutzung, welche die Gesundheit und Lebensqualität der Stadtbevölkerung beeinflussen. Diese Problematik ist eine Folge fortschreitender Urbanisierung sowie einer steigenden individuellen Nachfrage nach Mobilität, Gütern und Dienstleistungen. Mit dem Ziel die ökologische Nachhaltigkeit in Städten zu gewährleisten, streben Stadtverwaltungen und Politik eine Verkehrsreduzierung sowie eine Senkung der Verkehrsemissionen an.

Um einen effizienteren und umweltfreundlicheren Stadtverkehr zu fördern, konzentriert sich die vorliegende kumulative Dissertation auf alternative Transportkonzepte. Dazu werden wissenschaftliche Methoden und Modelle aus dem interdisziplinären Forschungsfeld der Wirtschaftsinformatik genutzt, mit Operations Research-, Transport- und Logistikansätzen kombiniert und in verschiedenen Fachbeiträgen analysiert. In diesem Zusammenhang werden verschiedene Verkehrskonzepte hinsichtlich Optimierung und Akzeptanz untersucht, um relevante Akteure in ihrer Entscheidungsfindung zu unterstützen. Das übergeordnete Thema des Stadtverkehrs wird in dieser Dissertation in die Themenkomplexe *urbane Mobilität* (Teil A) im Hinblick auf den Personenverkehr, sowie *urbane Logistik* (Teil B) mit dem Schwerpunkt auf der Lieferung von Gütern und Dienstleistungen unterteilt. Im Rahmen von Teil A werden Ansätze zur Carsharing-Optimierung auf verschiedenen Planungsebenen vorgestellt. Darüber hinaus wird die Nutzerakzeptanz von Ridepooling untersucht. Teil B präsentiert mehrere Optimierungsmodelle für alternative urbane Paket- und E-Grocery-Zustellkonzepte und empfiehlt dabei verschiedene Netzwerkstrukturen und Transportfahrzeuge. Durchgeführte kundenseitige Erhebungen zur beabsichtigten Nutzung verschiedener Logistikkonzepte geben Logistikdienstleistern und Entscheidungsträger wertvolle Handlungsempfehlungen.

Die vorgestellten Ansätze mit ihren jeweiligen Ergebnissen ermöglichen eine zielgerichtete Unterstützung hinsichtlich der Entscheidungsfindung auf Grundlage quantitativer Daten. Aufgrund des kontinuierlichen urbanen Verkehrsanstiegs wird die Bedeutung entsprechender Entscheidungsunterstützung, ebenso wie das Verständnis der wichtigsten Motive für die Nutzung bestimmter Dienstleistungen in Zukunft weiter zunehmen. Durch die zur Verfügung gestellten urbanen Mobilität- und Logistikkonzepte trägt diese Dissertation zur Verbesserung der wirtschaftlichen, sozialen und ökologischen Nachhaltigkeit in Städten bei.

Schlagworte: Wirtschaftsinformatikforschung, Entscheidungsunterstützung, Operations Research, Akzeptanzforschung, Urbaner Transport, Urbane Mobilität, Urbane Logistik, Nachhaltigkeit.

II. Management Summary

In an era dominated by ongoing urbanization, rising individual mobility needs, continuous growth of e-commerce, as well as rising demand for all types of goods and services, the efficient transport within cities becomes a major challenge. Resulting transport activities lead to increased traffic, congested road networks, and different kinds of pollution. To reduce these negative externalities on urban inhabitants' health and quality of life, politics and city authorities are interested in optimizing urban transport activities. Action is required to alleviate the problems described, while maintaining city dwellers' needs. As standalone measures, such as the introduction of emission ceilings or the sole use of eco-friendly vehicles do not overcome the entirety of the problems mentioned, alternative transport concepts have to be developed. These concepts in combination with regulations may be able to drastically affect urban road networks, but at the same time city dwellers' and companies' daily transportation routines and costs. Alternative ways of transport and respective acceptance of these concepts by both stakeholders is therefore indispensable. In this regard, it may have beneficial effects that our population is increasingly aware of economic, social, and environmental sustainability (Dedrick, 2010).

The methods and models of the interdisciplinary information systems (IS) domain can be applied to derive solutions for transport related issues by information usage and processing to enable appropriate decisions on sustainable actions (Watson et al., 2010). Development and interpretation of optimization models as well as quantitative surveys provides decision support to identify best possible solutions and recommendations regarding the investigated transport concepts.

In this cumulative dissertation, the overarching topic of urban transport is divided into urban mobility (part A) and urban logistics (part B), which are both based on related research articles. Part A focuses on new mobility services (NMS) related to the concept of sharing, which are facilitated through modern information and communication technologies (ICT). In more detail, carsharing is analyzed in terms of optimization potential, while ridepooling is examined regarding its customer acceptance. Part B mainly focuses on transport processes of courier, express, and parcel (CEP) service and e-grocery providers with investigations in terms of optimization and acceptance.

In the following, a brief summary of addressed solution approaches is presented.

The initial focus in *part A* is on carsharing optimization approaches. Carsharing is a mobility concept for individuals to use a car without owning it. The contained research contributions deal with station-based carsharing concepts. Users pay fees based on the period of use and/or distance for renting a company-owned car at fixed locations. Regarding optimization purposes, strategic network planning is divided from tactical fleet assignment and operative revenue and pricing decisions. All planning stages are addressed as subject of different optimization approaches and described in the following.

The accessibility of carsharing stations is described as most relevant factor for the long-term success of a carsharing organization. The placement of stations is a challenging task and should be as close as possible to the demand locations of customers to best satisfy existing customer demand. The developed approach is based on a definable service level, which allows to exclude areas with lower demand from network planning. The respective optimization model maximizes the annual profit of a station-based two-way carsharing organization concerning the strategic station and tactical fleet planning. Besides other features, the model allows to permit the establishment of a heterogeneous fleet, take account for a preset maximum CO_2-threshold, and limit the distance between stations and customer to optimally satisfy demand. Based on a mathematical model, a decision support system (DSS) is introduced (see Figure 1).

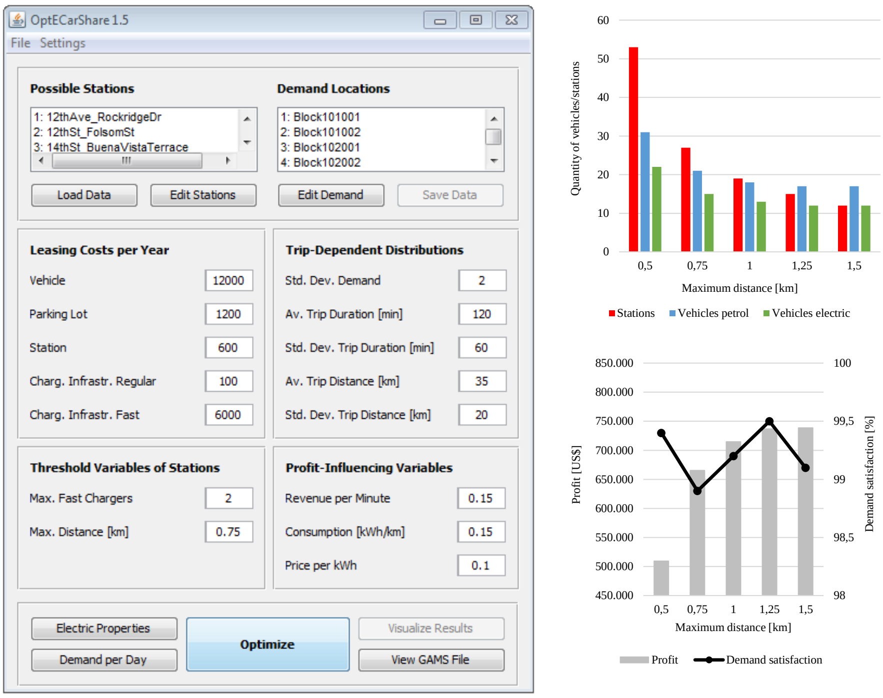

Figure 1. Strategic Carsharing Optimization: Decision Support System and Results; Based on Sonneberg et al. (2015; 2020).

The DSS allows the setting of desired parameters and enables decision makers to solve their own scenarios without optimization knowledge. Irrespective of the investigation area chosen, the maximum distance between customers and assigned stations depicts one of the most crucial factors for network generation, corresponding vehicle deployment, and resulting profit (see Figure 1). Likewise, the choice and size of the investigation area with its underlying demand has a major influence on network design and resulting costs. The preset emission limit mainly influences the vehicle selection, but not the station network itself. Based on further generalizations, carsharing providers are supported in strategic and tactical planning of stations and fleet assignment for a more profitable operation (section 2).

The next introduced concept focuses on the tactical decision level of carsharing. The accessibility and availability of vehicles in station-based two-way carsharing is described as one of the most significant factors to meeting customers' demands. With locations of carsharing stations defined, the developed optimization model enables tactical vehicle distribution based on fluctuating demands while considering emission limits. The model and performed benchmarks permit decision support for carsharing providers in response to monthly demand fluctuations while taking into account customer satisfaction, sustainability, and profitability (section 3).

The last optimization approach of part A focuses on carsharing revenue management at operative level. While considering different vehicle types, the mathematical model performs demand-side management preferring profitable journeys over of less profitable short-term reservations. The approach provides assistance for carsharing providers in terms of revenue management for a more efficient vehicle utilization (section 4).

Part A is completed by an investigation on the customer acceptance of ridepooling, which applies and evaluates a survey-based IS approach. In ridepooling, users hail a shuttle to designated pick-up points near their location; passengers are matched and transported together in company-owned vehicles. While theoretical calculations suggest positive impact on traffic and emissions, the service is currently not widely utilized. Therefore, the approach focuses on the exploration of factors that influence the customers' acceptance of ridepooling to derive recommendations for ridepooling providers (Figure 2). As practical implications, ridepooling providers should highlight the usefulness of the service,

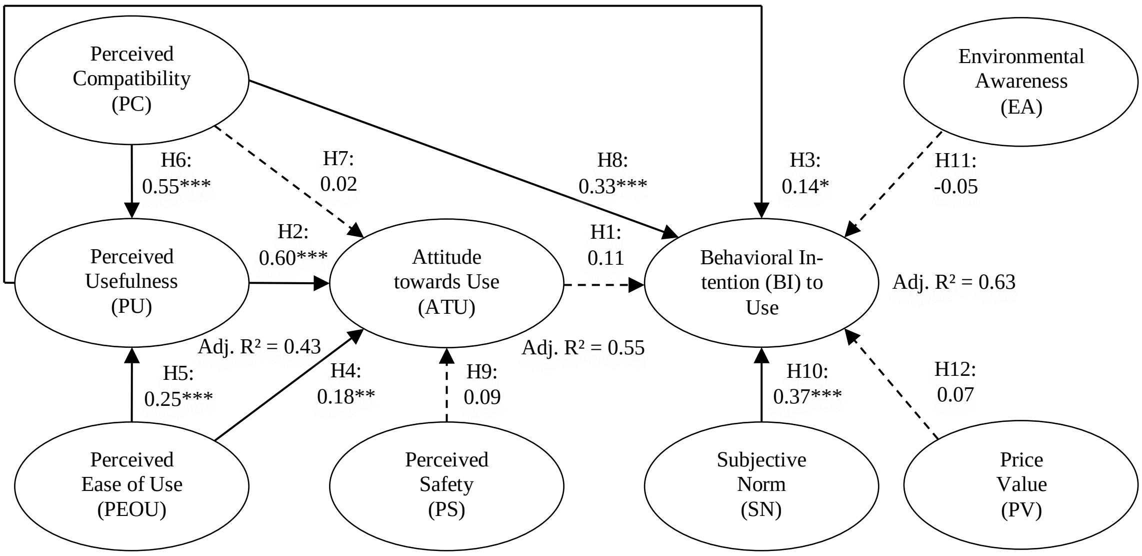

Figure 2. Results of the Path Analysis; Based on Werth et al. (2020).

offer an easy booking process, and convince early adopters to gain higher usage rates. Environmental benefits, prices, and safety issues are in customers' view not relevant due to the typical irregular use for occasional trips (section 5).

Part B of this dissertation focuses on urban logistics. Rising individual demand for goods and services, driven and supported by the growth of e-commerce, require efficient and sustainable transport solutions. Today, transport providers perform their logistics activities mostly with conventional powered vans and trucks. To reduce congestion and pollution, the implementation of regulatory or incentive measures is necessary and needs to be combined with sustainable logistics concepts and strategies making use of new technologies and additional infrastructures. One respective idea is the installation of transshipment points in combination with alternative delivery vehicles. However, current pilot projects in this regard mostly focus on solutions tailored to CEP service providers and further investigations are required to support a sustainable way of urban life through less urban road transport.

The first introduced concept does therefore not exclusively focus on CEP service providers; it permits a generic optimization of routing for various kinds of urban goods and service transporters. With optimized routes, the company can save costs, while the environment benefits from reduced emissions. Based on a heuristic solution approach covering a bandwidth of possible routing specifics, a DSS is developed. In Figure 3, the user interaction and the system architecture of the DSS is illustrated. Users without optimization knowledge or programming skills are able to optimize their customized business

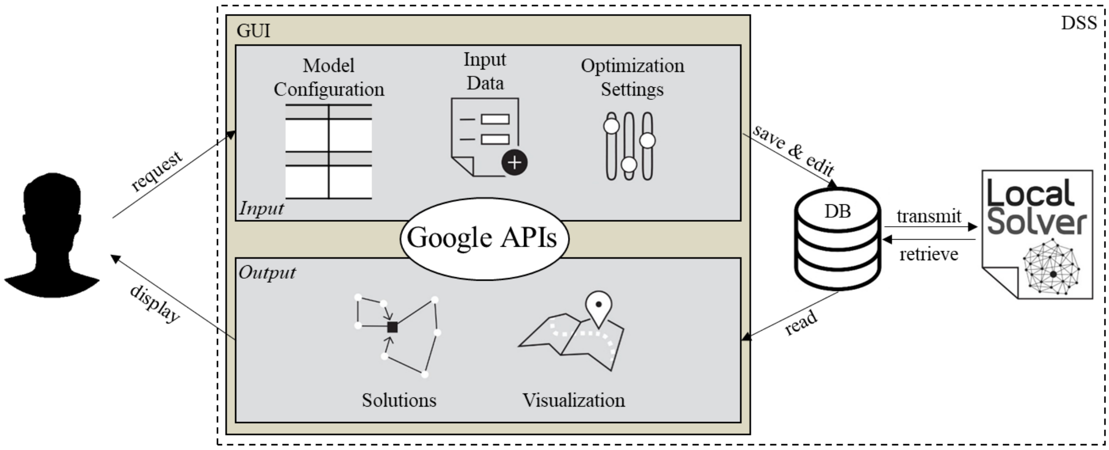

Figure 3. User Interaction and System Architecture of the DSS; Based on Leyerer et al. (2019a).

cases. The tool is evaluated by a proof-of-concept. Two real-world application examples highlight the efficient solution performance as well as resulting savings in terms of distance and emission (section 6).

The remaining sections of the part urban logistics account for the rising percentage of parcels forecasted in next years and focus on e-grocery and CEP service providers.

The first respective concept supports simultaneous optimization of urban micro-depot locations, vehicle fleet assignment, and routes. The consideration of urban micro-depots reduces the last mile to customers' homes and allows for the implementation of alternative delivery vehicles. The developed mathematical model minimizes the monthly operating costs while deploying heterogeneous fleets and emission limits. The following Table 1 visualizes exemplary results of the conducted benchmarks. When incorporating hub operation, (fixed and variable) vehicle, and personnel costs, a CO_2-neutral delivery (tank-to-wheel emissions) only amounts to additional cost of about 6%. In this case, a heterogeneous fleet consisting of electric cargo bicycles (eCB), electric cargo tricycles (eCT), and electric powered vans (eVan) is suggested to be deployed. Based on further scenario

Table 1. Benchmarks for Different CO_2-Emission Levels for A2; Based on Leyerer et al. (2019b).

Max. CO_2-level [gCO_2/km]	Total costs [€/month]	Used hubs [#]	Used vehicles [#]							Approx. distance covered [km/day]			Total emissions [gCO_2/day]	Average emissions of vehicle fleet [gCO_2/km]
			eCB	*eCT*	*Car*	*eCar*	*Van*	*eVan*	∑	Diesel driven	Electric driven	∑		
200	187,465	37	2	-	-	-	60	-	62	300.2	11.9	312.1	60,038	192.3
150	189,156	36	19	-	-	-	48	-	67	240.0	121.0	361.0	48,000	133.0
100	191,242	27	37	-	-	-	36	-	73	180.1	187.5	367.6	36,027	98.0
50	195,819	33	51	-	2	-	18	6	77	115.2	341.3	456.5	20,820	45.6
0	199,091	21	54	2	-	-	-	22	78	-	467.4	467.4	0	0.0

analyses, a heterogeneous delivery fleet in combination with micro-depots is more cost-efficient than a homogeneous fleet due to the vehicles' varying (dis-)advantages. The model is incorporated into a user-friendly DSS, which supports decision makers in finding appropriate solutions for a more sustainable urban delivery of goods (section 7).

The subsequently introduced model focuses on delivery by means of autonomous unmanned ground vehicles (AUGV). These robots move autonomously within public space on footpaths, relieve stressed road networks, and are predominantly used for small-sized same-day or instant deliveries. The developed mathematical model optimizes station selection in terms of number and location, related customer assignment, number of AUGV, as well as corresponding routes. An application example based on different scenarios allows to derive implications and recommendations in terms of efficient parcel delivery for CEP service providers and AUGV manufacturers (section 8).

The delivery of online-ordered groceries (e-grocery) is part of next investigation. Compared to conventional operation with vans, a novel concept for e-grocery delivery is introduced that employs refrigerated grocery lockers. These are spread throughout the city and allow for self-collection by customers or delivery via ECB. Figure 4 visualizes the concept and the calculation stages of the 3-echelon optimization model. With the overall

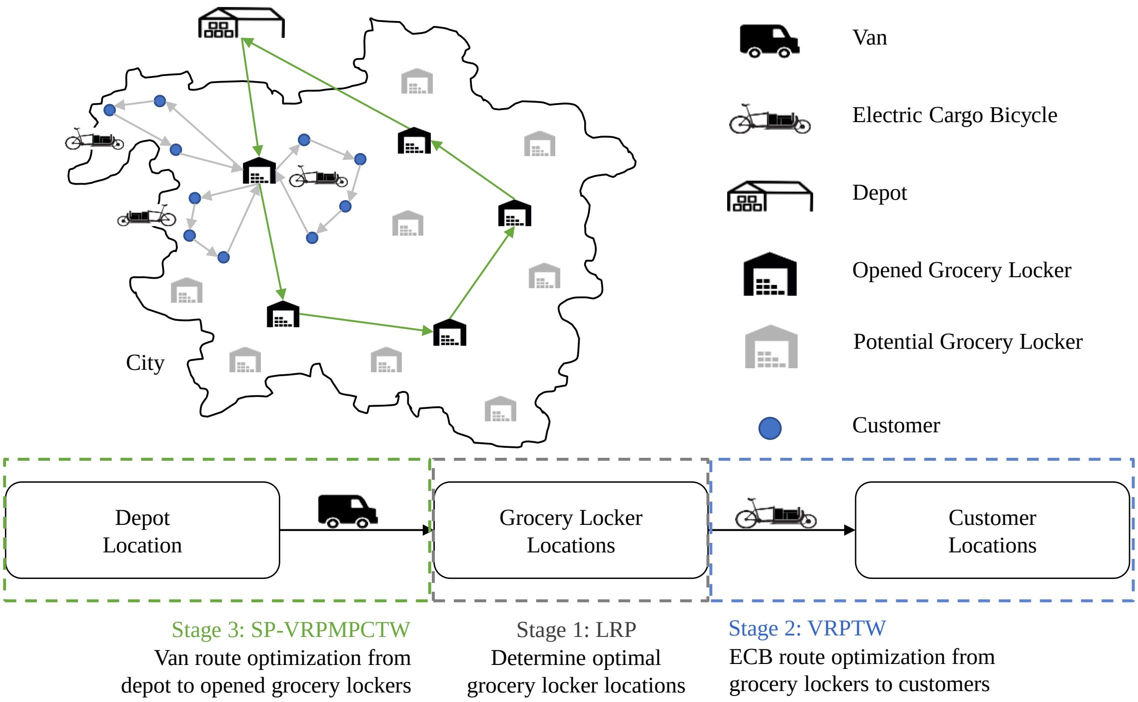

Figure 4. Overview of the Proposed E-Grocery Logistics Concept; Based on Leyerer (2020).

goal of costs minimization, grocery lockers are established, ECBs are assigned, and routes for grocery locker and home deliveries planned. Sensitivity analyses include varying ratios of home delivery and self-collection customers, the maximum distance between grocery lockers and assigned customers, as well as a comparison to the conventional delivery. Results highlight the impacts on distance travelled, emitted emissions, required space, and resulting costs. Decision makers are supported in planning and implementing a more sustainable and urban road relieving delivery concept for e-groceries (section 9).

End customer acceptance regarding 14 different delivery alternatives of the CEP service and e-grocery industry is investigated in the final article of this dissertation. With the logistics concepts previously examined in terms of optimization, their successful implementation heavily depends on the acceptance and application of end customers. To provide decision support in this regard, factors for the acceptance were analyzed and interpreted by conducting survey-based IS research on different concepts. The 14 concepts range from various forms of self-collection and unattended access for various types of properties to delivery via alternative transport vehicles. Elaborated factors for most concepts are perceived efficiency, social influence, and habit. In terms of recommendations, CEP service and e-grocery providers should focus on punctual delivery in offered short timeframes with tracking opportunities, advertising measures, provision of positive customer feedback, and promotional videos to highlight the advantages of the concepts, as well as the easy implementation in daily behavioral patterns and the provision of incentives (section 10).

After presenting the related research articles as core elements of the cumulative dissertation, an overall discussion critically reviews these contributions in context of the overarching topic of urban transport. Resulting contributions derived during the time as research assistant, limitations regarding the topics as well as the research methods of IS, and future research on urban transport are presented (section 11).

In summary, this dissertation presents optimization and acceptance approaches to address the problems of ongoing urbanization, rising individual needs, and resulting externalities on urban road networks and city dwellers. Thus, the dissertation contributes to increased economic, social, and environmental sustainability by applying different theoretical IS methods as foundation for the suggested practical solutions.

III. Table of Contents

IV. List of Figures

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VI. List of Abbreviations

ADR	Action Design Research
AIS	Association for Information Systems
AMCIS	Americas Conference on Information Systems
API	application programming interface(s)
ATU	attitude toward use
AU	actual usage
AUAV	autonomous unmanned aerial vehicle(s)
AUGV	autonomous unmanned ground vehicle(s)
BI	behavioral intention
BMBF	German Federal Ministry of Education and Research [Bundesministerium für Bildung und Forschung]
CB-SEM	covariance-based structural equation modeling
CEP	courier, express, and parcel
CO_2	carbon dioxide
DB	database
DSR	Design Science Research
DSS	decision support system(s)
EA	environmental awareness
eCB	electric cargo bicycle(s)
ECIS	European Conference on Information Systems
eCT	electric cargo tricycle(s)
EE	effort expectancy
EURO	European Operational Research Societies
FC	facilitating conditions
GAMS	General Algebraic Modeling System
GUI	graphical user interface
HICSS	Hawai'i International Conference on System Sciences
HM	hedonic motivation
HT	habit
ICIS	International Conference on Information Systems
ICOR	International Conference on Operations Research
ICT	information and communication technologies
IF	impact factor
IKT	Informations- und Kommunikationstechnologie(n)
IS	information system(s)
IT	information technology
JQ3	JOURQUAL 3
LMD	last mile delivery
LRP	location routing problem(s)

LSP	Local Search Programming
MILP	mixed integer linear problem
MINLP	mixed integer non-linear problem
MKWI	Multikonferenz Wirtschaftsinformatik
NMS	new mobility service(s)
NP-hard	non-deterministic polynomial-time hard
OR	operations research
PC	perceived compatibility
PE	perceived expectancy
PEOU	performance ease of use
PLS	partial least square
PLS-SEM	partial least square structural equation modeling
PS	perceived safety
PU	perceived usefulness
PV	price value
R^2	coefficient of determination
SE	sustainability expectancy
SI	social influence
SN	subjective norm
SWOT	strengths, weaknesses, opportunities, threats
TAM	Technology Acceptance Model
TCO	total costs of ownership
UB	use behavior
UTAUT	Unified Theory of Acceptance and Use of Technology
VHB	Verband der Hochschullehrer für Betriebswirtschaft [German academic association for business research]
VRP	vehicle routing problem(s)
WI	International Conference on Wirtschaftsinformatik
WKWI	Wirtschaftsinformatik-Orientierungsliste der Wissenschaftlichen Kommission für Wirtschaftsinformatik [business informatics guidelines of the scientific commission for business informatics in the association of professors for business administration]

VII. Chronological Overview of Publications and Task Allocation

The following chronological overview covers 22 research publications, which form the foundation of this cumulative dissertation. The dissertation is thereby mainly based on ten accepted, peer-reviewed papers published in different conference proceedings (e.g., proceedings of the International Conference on Information Systems) and journals (e.g., EURO Journal on Decision Processes). Additionally, nine articles were published within the IWI Discussion Paper Series and one article is forthcoming as book chapter. Two articles are submitted to different journals and currently under review. Table 2 provides an overview of the publications contained within this dissertation.

The vast majority of articles contribute to challenges related to urban transport in the fields of urban mobility and urban logistics. Other research contributions arose in context of doctoral courses. All publications were written in collaboration with different co-authors. In total, twenty-three co-authors were involved in the research projects. The most important co-authors for the dissertation were Michael H. Breitner, Maximilian Heumann, Kathrin Kühne, Max Leyerer, and Oliver Werth (alphabetical order). Additionally, Nadine Guhr and Jens H. Passlick, as well as several Economics and Management students, made important contributions to projects that were essential for publication.

Besides title, authors, and outlets, Table 2 assigns three different ratings or quality indicators to each publication. The first rating is the *Wirtschaftsinformatik-Orientierungsliste der Wissenschaftlichen Kommission für Wirtschaftsinformatik* (WKWI) (business informatics guidelines of the scientific commission for business informatics in the association of professors for business administration). The rating provides the perspective of the German information systems (IS) community and assesses journals and conference proceedings in terms of relevance for the information systems domain from “A” to “C” (Heinzl et al., 2008). The next column represents the rating of the *Verband der Hochschullehrer für Betriebswirtschaft* (VHB) (German academic association for business research) called JOURQUAL in version 3 (JQ3) (Hennig-Thurau et al., 2015). Based on this classification of the VHB, the rating assigns relevant scientific outlets to grades from “A+” to “D”. The third rating is called impact factor (IF) indicating the annual average number of citations that recent articles published in a certain journal received. The IF is published annually within the Journal Citation Reports issued by *Clarivate Analytics*; the values assigned in Table 2 refer to the current version (Clarivate Analytics, 2019).

Table 2. Chronological Overview of Publications.

#	Date	Title	Order of Authors	Outlet	WKWI	JQ3	IF	Section	Appen-dix
22	06/2020	Shortening the Last Mile of E-Grocery: Optimizing a New Logistics Concept for Urban Areas	Leyerer, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H.	Smart Cities	-	-	-	B-9	V
21	02/2020	Optimization of Station-based Carsharing Networks: Increasing Sustaina-bility through Heterogeneous Fleets and Emission Control	Sonneberg, M.-O., Kühne, K., Breitner, M.H.	IWI Discussion Paper Series, 94, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	A-2	U
20	02/2020 submitted	Behavioral Intention to Use Ridepooling Services - Empirical Insights and Recommendations	Werth, O., Sonneberg, M.-O., Leyerer, M., Breitner, M.H.	Transportation Research Part A	-	B	3.693	A-5	T
19	12/2019 submitted	Trends of Top Information Systems Research by Region, Outlet, and Emergence	Guhr, N., Sonneberg, M.-O., Pass-lick, J.H., Werth, O., Breitner, M.H.	Journal of Information Systems and Technology Management	-	-	-	-	S
18	11/2019	Decision Support for Sustainable and Resilience-Oriented Urban Parcel Delivery	Leyerer, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H.	EURO Journal on Decision Processes	-	-	-	B-7	R
17	11/2019	Chancen, Herausforderungen und Voraussetzungen von Cargotram-Pro-jekten	Sonneberg, M.-O., Hempen, M., Vollert, J., Breitner, M.H.	IWI Discussion Paper Series, 93, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	-	Q
16	10/2019	Individually Optimized Commercial Road Transport: A Decision Support System for Customizable Routing Problems	Leyerer, M., Sonneberg, M.-O., Heumann, M., Kammann, T., Breitner, M.H.	Sustainability	-	C	2.592	B-6	P
15	08/2019	Customer Acceptance of Urban Logistics Delivery Concepts	Sonneberg, M.-O., Werth, O., Kohzadi, H., Kraft, M., Neels, B., Breitner, M.H.	IWI Discussion Paper Series, 91, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	B-10	O
14	03/2019	Analysis of Augmented Reality Applications within the German Auto-motive Industry	Blacha, P., Kraft, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H.	IWI Discussion Paper Series, 88, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	-	N
13	02/2019	An Empirical Study of Customers' Behavioral Intention to Use Ridepool-ing Services – An Extension of the Technology Acceptance Model	Sonneberg, M.-O., Werth, O., Leyerer, M., Wille, W., Jarlik, M., Breitner, M.H.	Proceedings of the 14th International Conference on Wirtschaftsinformatik (WI) 2019, Siegen, Germany.	A	C	-	A-5	M
12	01/2019	Autonomous Unmanned Ground Vehicles for Urban Logistics: Optimiza-tion of Last Mile Delivery Operations	Sonneberg, M.-O., Leyerer, M., Kleinschmidt, A., Knigge, F., Breitner, M.H.	Proceedings of the 52nd Hawai'i International Conference on System Sciences (HICSS) 2019, Grand Wailea, Maui, Hawaii, USA.	B	C	-	B-8	L
11	11/2018 forthcoming	Station-based Electric Carsharing: A Decision Support System for Net-work Generation	Sonneberg, M.-O., Breitner, M.H.	In: Degirmenci et al. (eds.) 2020: Electric Vehicles in Shared Fleets: Mobility Management, Business Models and Decision Support Systems. Singapore: World Scientific.	-	-	-	A-2	K
10	08/2018	Decision Support for Urban E-Grocery Operations *Winner of Best Conference Paper - Award*	Leyerer, M., Sonneberg, M.-O., Breitner, M.H.	Proceedings of the 24th Americas Conference on Information Systems (AMCIS) 2018, New Orleans, Louisiana, USA.	B	D	-	B-9	J
9	06/2018	TCO-Comparison of Fuel and Electric Powered Taxis: Recommenda-tions for Hannover	Stieglitz, M., Sonneberg, M.-O., Breitner, M.H.	IWI Discussion Paper Series, 84, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	-	I
8	03/2018	Ein Entscheidungsunterstützungssystem zur Tourenplanung am Beispiel eines innovativen Lebensmittel-Lieferkonzeptes	Gebski, S.A., Czerwinski, P., Leyerer, M., Sonneberg, M.-O., Breitner, M.H.	Proceedings of the 10th Multikonferenz Wirtschaftsinformatik (MKWI) 2018, Lüneburg, Germany.	C	D	-	-	H
7	01/2018	Revenue Management Meets Carsharing: Operating the Daily Business	Broihan, J., Möller, M., Kühne, K., Sonneberg, M.-O., Breitner, M.H.	Proceedings of the 27th International Conference on Operations Research (ICOR) 2016, Hamburg, Germany.	-	D	-	A-4	G
6	06/2017	Ecological & Profitable Carsharing Business: Emission Limits & Hetero-geneous Fleets	Kühne, K., Sonneberg, M.-O., Breitner, M.H.	Proceedings of the 25th European Conference on Information Systems (ECIS) 2017, Guimarães, Portugal.	A	B	-	A-3	F
5	02/2017	Visualisierung von Verkehrsdaten der Landeshauptstadt Hannover	Thermann, C., Sonneberg, M.-O., Breitner, M.H.	IWI Discussion Paper Series, 81, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	-	E
4	11/2016	Analyse innovativer Logistikkonzepte für urbane Paketdienstleister	Dang, V.K., Sonneberg, M.-O., Breitner, M.H.	IWI Discussion Paper Series, 80, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	-	D
3	10/2016	IKT-basierte Geschäftsmodellinnovationen im Gütertransport: Markt-übersicht und Analyse	Neels, B., Sonneberg, M.-O., Breitner, M.H.	IWI Discussion Paper Series, 78, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	-	C
2	01/2016	Social Network Usage of Financial Institutions: A SWOT Analysis based on Sparkasse	Sonneberg, M.-O., Wei Cao, D., Breitner, M.H.	IWI Discussion Paper Series, 72, Institut für Wirtschaftsinfor-matik, Leibniz Universität Hannover.	-	-	-	-	B
1	12/2015	A Decision Support System for the Optimization of Electric Car Sharing Stations	Sonneberg, M.-O., Kühne, K., Breitner, M.H.	Proceedings of the 36th International Conference on Information Systems (ICIS) 2015, Fort Worth, Texas, USA.	A	A	-	A-2	A

All publications were written in collaboration. The task sharing of each article in combination with a short introduction to the respective topic is described in the following.

The article "A Decision Support System for the Optimization of Electric Carsharing Stations" (Sonneberg et al., 2015 and Appendix A) deals with the strategic and tactical planning of station-based carsharing networks and presents a mathematical model as well as a related DSS to optimize station locations and corresponding fleet assignment. The entire team of authors developed the idea of the article. I supervised the research process. Kathrin Kühne and I wrote the foundations and the computational study. I was responsible for the methodological classification and developed the optimization model and the DSS. I authored the discussion section and presented the article at the 36th International Conference on Information Systems (ICIS) 2015 in Fort Worth, Texas, USA.

The article "Social Network Usage of Financial Institutions: A SWOT Analysis based on Sparkasse" (Sonneberg et al., 2016 and Appendix B) shows the Facebook activities of the *Sparkasse* and emphasizes chances and risks of the organization as well as its environment to derive recommendations for action. Danny Wei Cao developed the idea of the paper. Danny Wei Cao and I conducted the data generation and wrote the research methodology collaboratively. I was responsible for the structuring of the article and wrote the foundations as well the discussion section.

The article "IKT-basierte Geschäftsmodellinnovationen im Gütertransport: Marktübersicht und Analyse" (Neels et al., 2016 and Appendix C) deals with an overview of existent information and communication technology (ICT) related urban logistics business models and their application. I developed the concept and idea of the underlying approach. Bjarne Neels wrote the foundations and the discussions. With my assistance, Bjarne Neels was responsible for the market overview and classification.

The article "Analyse innovativer Logistikkonzepte für urbane Paketdienstleister" (Dang et al., 2016 and Appendix D) presents an overview of urban logistics concepts for courier, express, and parcel (CEP) service providers and classifies these in terms of environmental effects and customer acceptance-related impacts. I generated the idea for the research project. Vi K. Dang wrote the foundations. I supported Vi K. Dang during the evaluation process and corresponding discussion of the article.

The article "Visualisierung von Verkehrsdaten der Landeshauptstadt Hannover" (Thermann et al., 2017 and Appendix E) is based on an investigation of visualization techniques to identify traffic flows and congested zones by example of the city of Hannover. I developed the idea and the structure of the article. Christoph Thermann was responsible for the foundations and the visualization. I supported him during the entire creation process. Collaboratively, we wrote the discussion.

The article "Ecological & Profitable Carsharing Business: Emission Limits & Heterogeneous Fleets" (Kühne et al., 2017 and Appendix F) focuses on tactical fleet optimization regarding demand fluctuations of station-based carsharing services. Kathrin Kühne had the idea of the research approach, coordinated the writing process, and was responsible for the foundations. I wrote the methodological section. Together, we developed the mathematical model, conducted the computational study, and discussed obtained results. I presented the approach and its results at the 25th European Conference on Information Systems (ECIS) 2017 in Guimarães, Portugal.

The article "Revenue Management Meets Carsharing: Operating the Daily Business" (Broihan et al., 2018 and Appendix G) presents an optimization approach for demand-side management of bookings in the carsharing field. Kathrin Kühne and I had the idea of this research topic and structured the paper. Justine Broihan and Max Möller developed the mathematical model. The foundations, the computational study, and the discussion were written in collaboration. Justine Broihan presented the article at the 27th International Conference on Operations Research (ICOR) 2016 in Hamburg, Germany.

The article "Ein Entscheidungsunterstützungssystem zur Tourenplanung am Beispiel eines innovativen Lebensmittel-Lieferkonzeptes" (Gebski et al., 2018 and Appendix H) presents an optimization approach with a corresponding DSS regarding a delivery concept for prepared dishes using scooters as transport vehicles. Sebastian A. Gebski and Patrick Czerwinski developed the underlying idea and created the mathematical model as well as the related DSS. Max Leyerer was responsible for the supervision, the introductory section, and the benchmarks. I contributed the methodological section and wrote the foundations. Max Leyerer and I discussed and critically reviewed the approach. Max Leyerer presented the article at the 10th Multikonferenz Wirtschaftsinformatik (MKWI) 2018 in Lüneburg, Germany.

The article “TCO-Comparison of Fuel and Electric Powered Taxis: Recommendations for Hannover” (Stieglitz et al., 2018 and Appendix I) presents an overview of collected data of the taxi sector in Hannover and relating calculations to determine under which circumstances electrically operated taxis are recommendable in terms of economic and environmental issues. Michael Stieglitz had the idea of the project, wrote the foundations, and was responsible for the data collection. Together, we created the discussions and recommendations.

The article “Decision Support for Urban E-Grocery Operations” (Leyerer et al., 2018 and Appendix J) introduces a new e-grocery supply concept, for which a related mathematical model was developed. The entire team of authors developed the idea of the paper. Max Leyerer coordinated the writing process of the article. Max Leyerer and I created the foundations and the optimization model in collaboration. Max Leyerer conducted the application examples while I was responsible for the discussion. Max Leyerer presented the article at the 24th Americas Conference on Information Systems (AMCIS) 2018 in New Orleans, Louisiana, USA. At the conference, the contribution was honored with the Best Paper-Award.

The article “Station-based Electric Carsharing: A Decision Support System for Network Generation” (Sonneberg and Breitner, 2020 and Appendix K) deals with an optimization approach for station planning in carsharing systems. Michael H. Breitner and I created the idea of the article. I developed the mathematical model, the DSS, and the related application example. Together, we wrote the discussion section.

The article “Autonomous Unmanned Ground Vehicles for Urban Logistics: Optimization of Last Mile Delivery Operations” (Sonneberg et al., 2019a and Appendix L) introduces an optimization approach for the distribution of parcels via delivery robots. Agathe Kleinschmidt had the idea of this study while I was responsible for the supervision. Agathe Kleinschmidt initially developed the optimization model that was enhanced by Florian Knigge, Max Leyerer, and me. Max Leyerer and I conducted the computational study collaboratively. I wrote the methodological classification, the foundations, and the discussion parts including limitations and contributions. I presented the article at the 52nd Hawai’i International Conference on System Sciences (HICSS) 2019, Grand Wailea, Maui, Hawaii, USA.

The article "An Empirical Study of Customers' Behavioral Intention to Use Ridepooling Services – An Extension of the Technology Acceptance Model" (Sonneberg et al., 2019b and Appendix M) deals with the customer acceptance of ridepooling services in Germany by applying a survey-based research. Wiebke Wille and Marvin Jarlik developed the main idea of the investigation. Oliver Werth coordinated the creation process of the article and wrote the methodology. Max Leyerer and I were responsible for the foundations. Wiebke Wille and Marvin Jarlik developed the survey by assistance of Oliver Werth and me. Oliver Werth, Wiebke Wille, and Marvin Jarlik conducted the data collection and the structural equation modeling. I analyzed and interpreted the results of the discussions with aid of Oliver Werth. Oliver Werth presented the article at the 14^{th} International Conference on Wirtschaftsinformatik (WI) 2019 in Siegen, Germany.

The article "Analysis of Augmented Reality Applications within the German Automotive Industry" (Blacha et al., 2019 and Appendix N) describes the usage and potentials of augmented reality applications of the German automotive sector using a SWOT-approach as theoretical foundation. Philip Blacha and Marvin Kraft had the idea of this research topic. The entire research team wrote the foundations collaboratively. Philip Blacha and Marvin Kraft conducted the data collection. Philip Blacha, Marvin Kraft, and I wrote the discussion regarding the approach and its results.

The article "Customer Acceptance of Urban Logistics Delivery Concepts" (Sonneberg et al., 2019c and Appendix O) discusses the acceptance of end customers regarding 14 urban logistics concepts for parcel and e-grocery deliveries by conducting a survey in combination with structural equation modeling. I had the idea of the study and coordinated the preparation of the article. Oliver Werth and I wrote the methodology. Human Kohzadi, Marvin Kraft, Bjarne Neels, and I authored the foundations collaboratively. I decided on the selected logistics concepts to be investigated. Jointly, we generated the hypotheses. Human Kohzadi, Marvin Kraft, and Bjarne Neels conducted the data collection. The entire author team contributed to the discussion section.

The article "Individually Optimized Commercial Road Transport: A Decision Support System for Customizable Routing Problems" (Leyerer et al., 2019a and Appendix P) focuses on decision support for routing purposes of several commercial road transporters. Tim Kammann, Max Leyerer, and I jointly developed the idea of the approach, while

Max Leyerer took care of the project coordination. Max Leyerer and I authored the foundations and methodology. Tim Kammann developed the optimization model and the DSS, while Max Leyerer and I supported him. Max Leyerer and Maximilian Heumann conducted the computational studies. Max Leyerer, Tim Kammann, and I wrote the discussion section.

The article "Chancen, Herausforderungen und Voraussetzungen von Cargotram-Projekten" (Sonneberg et al., 2019d and Appendix Q) deals with a concept for urban delivery purposes using the infrastructure of existing tram networks. I had the idea to examine this concept and supervised the paper development process. In collaboration, all authors contributed to the foundations. Marvin Hempen and Johannes Vollert were responsible for the elaboration of chances, challenges, and requirements of this concept. I investigated theoretical implementation for the city of Hannover. Jointly, the discussion was written.

The article "Decision Support for Sustainable and Resilience-Oriented Urban Parcel Delivery" (Leyerer et al., 2019b and Appendix R) presents a delivery concept consisting of micro-hubs in combination with heterogeneous vehicle fleets, which is subject to an optimization model. Max Leyerer had the idea to optimize the underlying concept and coordinated the creation of the article. Max Leyerer and Maximilian Heumann wrote the foundations. Max Leyerer and I developed the mathematical model and the corresponding DSS. Max Leyerer and Maximilian Heumann conducted the application examples. In collaboration, we wrote the discussion including contributions and limitations.

The article "Trends of Top Information Research by Region, Outlet, and Emergence" (Guhr et al., 2019 and Appendix S) focuses on the publication behavior within the IS domain to explore publication trends during a 20-year period. Nadine Guhr and I had the idea of the research topic. Nadine Guhr supervised the development process of the article and wrote the foundations as well as discussions. I wrote the research methodology section and was responsible for the collection and structuring of data. Nadine Guhr and I wrote the result presentation by assistance of Jens H. Passlick and Oliver Werth. Jens H. Passlick and I were responsible for graphics and tables. Collaboratively, we contributed to discussions, implications, and limitations.

The article "Behavioral Intention to Use Ridepooling Services - Empirical Insights and Recommendations" (Werth et al., 2020 and Appendix T) deals with the acceptance of potential ridepooling customers and extents the prior study of Sonneberg et al. (2019b).

Oliver Werth developed the idea of the study and was responsible for the supervision. Max Leyerer wrote the introduction of the article. I wrote the foundations, methodology, and literature review. Oliver Werth and I formulated the hypotheses. Oliver Werth performed the structural equation modeling to obtain the results of the approach. Collaboratively, we wrote discussions, contributions, and limitations.

The article "Optimization of Station-based Carsharing Networks: Increasing Sustainability Trough Heterogeneous Fleets and Emission Control" (Sonneberg et al., 2020 and Appendix U) presents an optimization approach for including a variety of vehicles into the fleet while simultaneously optimizing station locations. The author team developed the idea of the approach jointly. I took the lead and wrote the methodological parts. Kathrin Kühne and I edited the foundations together. I developed the optimization model and the approach for demand estimation. Kathrin Kühne and I conducted the computational study in collaboration. Kathrin Kühne assisted me during discussion of result and approach, critical considerations, and generalizations.

The article "Shortening the Last Mile of E-Grocery: Optimizing a New Logistics Concept for Urban Areas" (Leyerer et al., 2020 and Appendix V) focuses on the investigated concept for e-grocery deliveries of Leyerer et al. (2018) (Appendix J) and enhances the optimization approach in terms of practical applicability. Max Leyerer and I developed the idea of the concept. Max Leyerer was in charge of the coordination. I wrote the foundations. Max Leyerer and I developed the mathematical model. The entire research team conducted the computational study. Maximilian Heumann and I assisted Max Leyerer during establishment of discussions, contributions, and limitations.

Involved in each article of this cumulative dissertation and not explicitly mentioned in each paper is the participation of Michael H. Breitner. During the entire publication process, Michael H. Breitner guided and supported me. He taught me, how to write a scientific paper and helped me understand the requirements for acceptance in conferences and journals. In extensive discussions, he gave valuable hints and contributed his expertise as well as experience to my work. He also helped to fine-tune the articles to eventually bring them up to publication level.

1. Introduction

1.1. Research Motivation and Research Topics

The urban population, accounting for about 54% of the world's population, is growing rapidly and is expected to amount to 66% by 2050 (United Nations, 2014). Urbanization in combination with rising individual demand for all kinds of mobility, goods, and services and the unremitting growth of e-commerce leads to higher transportation demands in cities. These developments pose challenging risks of increased traffic and pollution, influencing health and urban populations' quality of life. The politics and city authorities are interested in reducing urban transport and its negative consequences for city dwellers. To keep cities clean and road traffic moving, action is required. Several laws to reduce greenhouse gas emissions are already addressing this challenge. As an example for the delivery industry, the European Commission released a *White Paper on Transport*, which demands for "essentially CO_2-free city logistics in major urban centers by 2030" (European Commission, 2011). Possible approaches to achieve this goal are the introduction of emission ceilings or the use of alternatively powered vehicles. If specified emission limits are exceeded, city authorities may ban conventionally powered vehicles from urban roads. To name only a few: Oslo and Hamburg temporarily ban diesel cars from heavily congested roads since January 2017 respectively May 2018 (Financial Times, 2017; Reuters, 2018); Beijing and Paris exclude vehicles with even/uneven-numbered registration plates on a daily basis since October 2013 respectively March 2014 if emission limits are exceeded (BBC, 2014; The Telegraph, 2013). Despite such vehicle bans, city dwellers must be supplied with goods and stay mobile to conduct necessary trips. The described regulations therefore affect city dwellers as well as companies and demonstrate the need for alternative urban transportation concepts using eco-friendly vehicles in an optimized manner. At the same time, these transport concepts must be accepted and ultimately used by city dwellers to achieve the goal of emission reductions in urban centers.

Concurrently, our society is becoming increasingly aware of economic, social, and environmental sustainability (Dedrick, 2010). This awareness is also recognized in the information systems (IS) domain where information is a prerequisite for making appropriate decisions on sustainable actions (Watson et al., 2010). The main task of the so-called Green IS domain is "the design and implementation of information systems that contribute to sustainability of business and social processes" (SIGGreen, 2018).

Following Watson et al. (2010), the foci in this domain vary by conceptualization, analyses, design, and impact of such systems. Based on studies of Malhotra et al. (2014) and Gholami et al. (2016), design and impact-oriented research is lacking. Since the IS domain is described as an interdisciplinary space (Hassan, 2014), elements of operations research (OR), transportation, and logistics are combined to support a more efficient and sustainable urban transport by providing solution-oriented contributions.

To achieve respective contributions, rational decision making is necessary to solve present problems. Especially in urban transportation contexts, decisions for concept planning require a huge amount of data and corresponding high investments for the resulting implementation. Decision support can be provided by means of optimization techniques but also by examination and interpretation of quantitative surveys. Optimization is subject to OR, whereby real-world problems are adapted to mathematical models and solved by a multitude of existing exact or heuristic techniques. Quantitative questionnaires and surveys are used to identify problems or to measure (potential) customer acceptance, adoption, and usage of an existing or planned business model. Both procedures should ideally be combined to minimize misinterpretations. In this context, decision assistance can be implemented into decision support systems (DSS), which are defined as "interactive computer-based systems that help people use computer communication, data, documents, knowledge, and models to solve problems and make decisions" (Power, 2002). For the application of a DSS, a decision maker does not necessarily understand the functionality nor the solution methods used in the system. In such systems, decision making is assisted, but not replaced. Through the simple comparison of different possibilities or alternatives, the decision maker is supported in finding best possible results for the underlying business case. For the abovementioned reasons, this cumulative dissertation focuses on decision aid for urban transport to provide solution-oriented and impactful contributions for relevant stakeholders, including city authorities, politics, mobility service providers, and urban logistics actors in various contexts (Gholami et al., 2016; Malhotra et al., 2014; Seidel et al., 2017).

With the overarching topic of urban transportation, a first step is to distinguish the term transport with regard to various characteristics (see Figure 5). In the context of physical transport, people and goods are moved. Thereby, passenger transport is separated from freight transport. In passenger transport, there are private journeys, such as commuting, shopping, and leisure transport; on the goods-moving side, private freight transportation is described as relocation or disposal transport (Arndt, 2010). Commercial transport is the business transport of passengers and/or goods. A distinction is made between commercial passenger transport (e.g., taxi industry), commercial freight transport (e.g., parcel industry) as well as commercial service transport (e.g., crafts industry), which moves both passengers and freight (Arndt, 2010). The term urban mobility encompasses all passenger transports; all freight and service transports are aggregated into the term urban logistics. Together, the two thematic complexes of urban mobility and urban logistics form the overarching theme of this dissertation, urban transport.

<table>
<tr><td colspan="10">Physical Transport</td></tr>
<tr><td colspan="5">Passenger Transport</td><td colspan="5">Freight Transport</td></tr>
<tr><td colspan="2" rowspan="2">Private Passenger Transport</td><td colspan="6">Commercial Transport</td><td colspan="2" rowspan="2">Private Freight Transport</td></tr>
<tr><td colspan="2">Commercial Passenger Transport</td><td colspan="2">Commercial Service Transport</td><td colspan="2">Commercial Freight Transport</td></tr>
<tr><td colspan="4">Urban Mobility</td><td colspan="6">Urban Logistics</td></tr>
<tr><td colspan="10">Urban Transport</td></tr>
</table>

Figure 5. Classification of Transport Modes; Adapted from Arndt (2010).

Topics of investigation in this dissertation are the urban mobility concepts of carsharing (private passenger transport) and ridepooling (commercial passenger transport), as well as urban logistics concepts (commercial service and freight transport). Carsharing and ridepooling can be classified as new mobility services (NMS) which are offered solely in cities. In contrast to private vehicle ownership and mass transit, they allow for individual trip purposes on a pay-as-you-use base permitting flexible and network-independent journeys (Kamargianni and Matyas, 2017). Alternative delivery services in urban logistics contexts focus on the commercial transport of goods and services within a city.

These concepts are only feasible by use of IS and information technology (IT) as well as a corresponding technological progress. Emerging developments such as digitalization, wireless connectivity, high-speed computing, accurate sensors, location data, and new pricing schemes serve as enabler for those alternative transportation concepts (Spulber et al., 2016). A more detailed description of the definitions and characteristics of the topics of carsharing and ridepooling is presented within part A of urban mobility (see primer to part A) respectively the topic of urban logistics (see primer to part B).

1.2. Research Methodologies and Research Design

In this cumulative dissertation, approaches of the two fundamental IS paradigms of design science and behavioral science were applied. The design science approach systematically seeks to create “new and innovative artifacts” (Hevner et al., 2004: 75). These artifacts include models, methods, constructs, design theories, and instantiations to address on-hand organizational problems (Adomavicius et al., 2008; Gregor and Hevner, 2013). Based on its problem-solving character, design science has its roots in the adjoining research domain of engineering. In contrast to that, behavioral science develops, verifies, and justifies theories to explain and predict human behavior in context of organization and technology (Hevner et al., 2004; Myers, 2013). Rooted in natural sciences, qualitative or quantitative methods such as questionnaires or surveys are applied to explore reasons for the intention to use as well as actual use of technologies and innovations (Myers, 2013). As both paradigms are contrasting, they complement each other within the IS domain to positively influence people, organizations, as well as technology (Ayanso et al., 2011; Hevner et al., 2004; Kuechler et al., 2007).

Design Science

The majority of research articles contained within this dissertation (eleven out of 22) investigate real-world transportation problems and their efficient solution. Therefore, the application of the design science research (DSR) approach is the method used most. When creating, specifying, and evaluating optimization models, the DSR approach is suitable for the tasks that need to be accomplished. Despite the existence of different DSR approaches (e.g., Peffers et al., 2007), the research projects of this dissertation follow the DSR guidelines of Hevner et al. (2004), because this approach best visualizes and explains the entire process of artifact generation within the scientific environment of the IS domain. Figure 6 illustrates the DSR approach based on Hevner et al. (2004) respectively Hevner (2007).

A DSR process is initiated by the relevance cycle. The motivational starting point is the society’s growing interest in sustainable urban transportation of people and goods. Due to the existence of corresponding research projects, the definition of requirements and acceptance criteria as well as objectives and targets ensure the actual relevance and importance of the underlying problems.

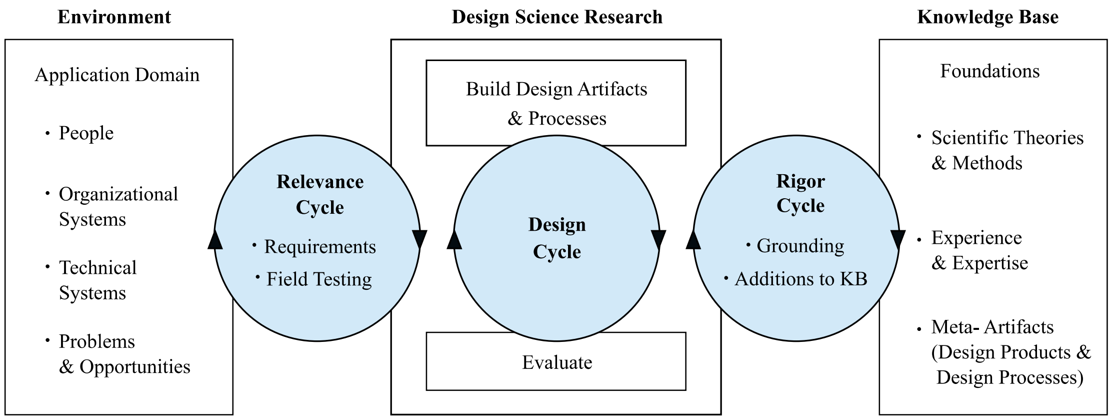


Figure 6. Research Design according to Design Science Research; Based on Hevner (2007)

The review of existing knowledge in the rigor cycle represents a second essential part of the DSR methodology. Comprehensive literature reviews, most often following the approach of Webster and Watson (2002), were conducted within the (urban) transportation literature, especially relating to approaches of the DSR, IS, and OR domains.

The design cycle is an iterative process using several build-and-evaluate loops, revising the design artifacts until a feasible level is reached (Hevner et al., 2004). These cycle iterations form a main part of the presented articles in this dissertation. The artifact development commences with design ideas based on existing models and additional requirements. Moreover, it evaluates and refines the current state of the created model and then concludes with the respective contribution to the research topic of urban transportation as final artifacts. For each of the eleven research projects, several cycles were conducted to ensure that environmental requirements are met on the one hand and scientific methods and existing expertise are considered on the other hand.

Finally, the resulting artifacts were tested extensively in different ways. Proper documentation and discussion of research results by means of the developed mathematical models and the DSS, as well as the conducted benchmarks allowed the addition of the artifacts to the knowledge base as part of the rigor cycle.

Within the introductory primers of part A and part B, a detailed DSR application of the research topics of urban mobility respectively urban logistics is presented following the visualization of Hevner (2007).

Behavioral Science

For the investigation of customer acceptance in urban transportation contexts, methods of behavioral science were applied. In literature, many different acceptance research approaches exist. The foundations of acceptance research were established through theories such as the *Diffusion of Innovation* (Rogers, 1962; Rogers, 2003), the *Theory of Reasoned Action* (Fishbein and Ajzen, 1975), and the *Theory of Planned Behavior* (Ajzen, 1985; Ajzen, 1991; Ajzen and Madden, 1986).

Adapted from these studies, the *Technology Acceptance Model* (TAM) was initially presented by Davis (1985). The goal of TAM was the development of an acceptance measure for the IS domain that can be used as a basic theory to explain the interconnection between the individuals' reaction of using a technology, the intention, as well as the resulting usage of it (Venkatesh et al., 2003). The TAM contains the constructs of perceived usefulness (PU), perceived ease of use (PEOU), attitude toward use (ATU), behavioral intention (BI) to use, and actual usage (AU). To investigate these constructs, hypotheses development as well as subsequent multivariate testing is necessary. Figure 7 illustrates the constructs of TAM and the corresponding interconnection depicted as arrows, which represents the hypotheses.

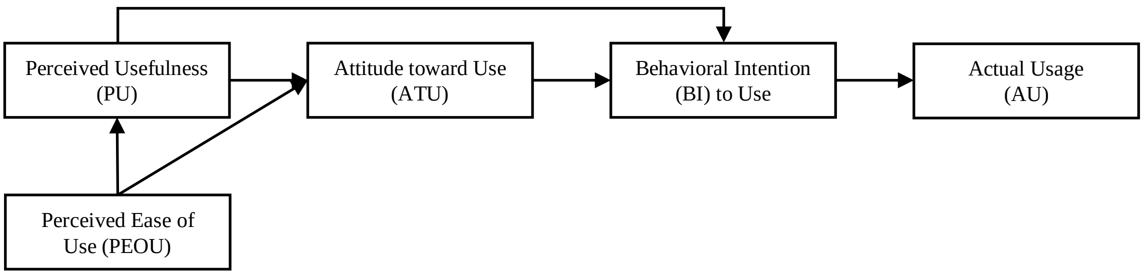


Figure 7. Structural Model of the TAM; Based on Davis et al. (1989).

The idea of TAM is based on individual beliefs, which determine and therefore affect the ATU as well as the AU of a technology in a distinct situation (Giang et al., 2017). Davis (1985: 16) defines beliefs as "the person's subjective probability that performing the target behavior will result in salient consequence". Beliefs serve as intermediaries of all external variables such as individual characteristics, which also may influence the usage of an innovation (Agarwal and Prasad, 1999). Therefore, beliefs have an indirect effect on the BI to use an technological innovation (Davis, 1985). In TAM, these beliefs consist of the two interacting factors PU and PEOU. Consequently, the ATU has a direct influence on the BI, and in result, on the AU of a technology, enabling researchers to measure the acceptance of an innovation at an early stage (Davis, 1985).

Originally, the TAM was developed to predict technology usage at workplaces, but it can also be used to predict customer behavior in a multiplicity of IS and IT circumstances (Gefen and Karahanna, 2003; Pavlou, 2003). For instance, TAM was successfully applied to measure the customer acceptance on technology-driven innovations such as online shopping, mobile services, or travelling with autonomous vehicles (Cheng et al. 2006; Lee et al., 2009; Lee et al., 2019). TAM serves as basic theory for several extensions with two of them, namely TAM2 (Venkatesh and Davis, 2000) and the *Unified Theory of Acceptance and Use of Technology 2* (UTAUT2) (Venkatesh et al., 2012) being further applied to technology-enabled innovations of urban transportation concepts (Rondan-Cataluña et al., 2015).

By applying the TAM to a technology, several empirical hypotheses for the constructs have to be developed or adapted. To test these hypotheses, multivariate analysis methods of covariance-based structural equation modeling (CB-SEM) or partial least square structural equation modeling (PLS-SEM) are necessary (Ringle et al., 2012). These methods are used to estimate the interconnections of the contained constructs and their relationship linking measured through a number of observable indicators (Vinzi et al., 2010). As multivariate analysis method in all behavioral science approaches, PLS-SEM was chosen due to the recommendations of Gefen et al. (2011). PLS-SEM has the advantages in terms of possibility to measure constructs with reflexive scales, applicability for exploratory research, and simultaneous testing of the measurement and the structural model (Gefen et al., 2011; Hair et al., 2016; Xu et al., 2014). Additionally, PLS-SEM is applicable in cases of small or not normal-distributed sample sizes or if the model is complex with a lot of estimated relationships (Hair et al., 2016).

In the context of ridepooling, the TAM2 was applied and expanded to serve as basis for the investigation regarding the customer acceptance of such services (section 5). To measure the customer acceptance of 14 different urban logistics concepts, the UTAUT2 framework serves as methodological foundation (section 10).

1.3. Structure of the Dissertation

This cumulative dissertation is a comprehensive synthesis of important publications. After presenting these publications, critical reflections on the topics dealt with, the research methods used, and the approaches developed are discussed and categorized within the overarching topic of urban transport. Figure 8 illustrates the structure of this dissertation.

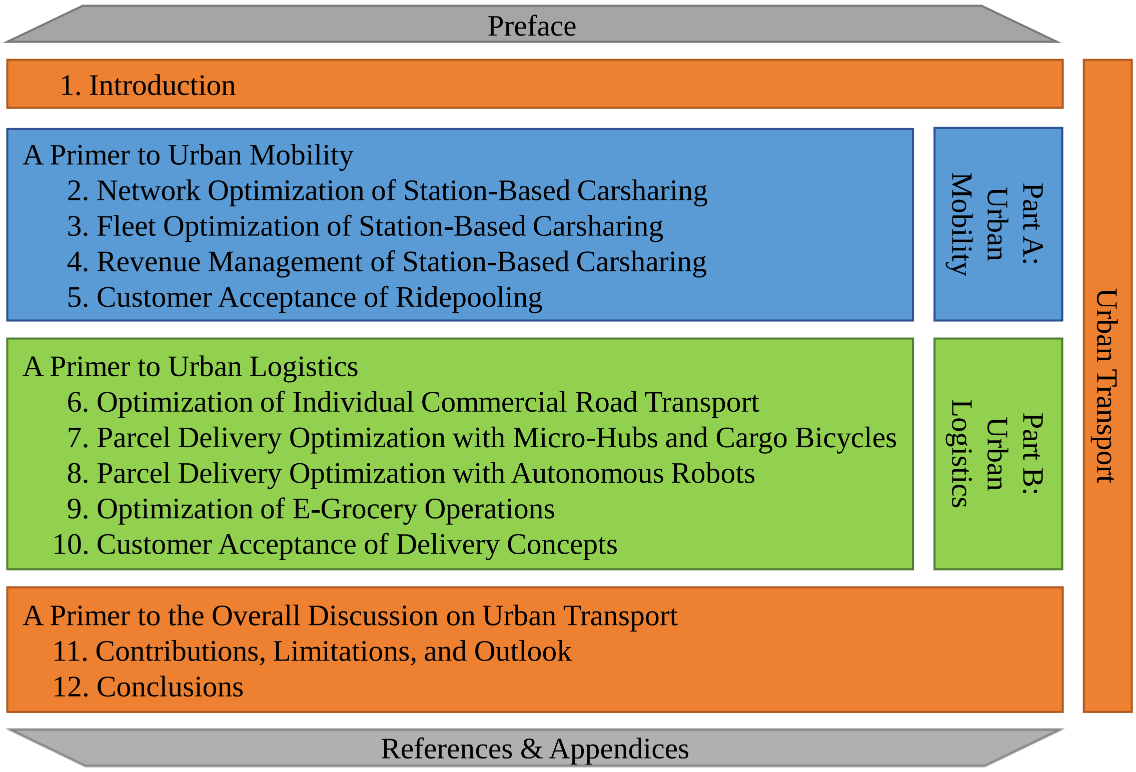


Figure 8. Structure of the Cumulative Dissertation.

In more detail, the dissertation begins with a preface including, inter alia, abstract, management summary, and the chronological overview of publications. Motivation for the investigated topics within the dissertation is elaborated in section 1. Further, the research topics are introduced and the underlying research methodologies as well as the chosen research design are illustrated.

Part A contains selected publications on the topic of urban mobility. A primer introduces the reader to the concept of urban mobility and compares the investigated services of carsharing and ridepooling. Besides current literature reviews, the research design is further investigated. Sections 2 to 4 deal with optimization approaches in the area of carsharing; section 5 examines the crucial factors for the customer acceptance of ridepooling services.

Subsequently, a thematic transition to part B, urban logistics, takes place via a corresponding primer. An in-depth explanation of the topic is given, including definitions, underlying research methods, and an overview of the current scientific literature. In the following, sections 6 to 9 present and discuss different approaches to the optimization of logistics processes in the field of urban environments. Section 10 investigates the customer acceptance of several urban logistics concepts applying a behavioristic approach.

Section 11 unites the two parts of urban mobility and urban logistics. It discusses overall contributions as well as limitations and presents future research possibilities regarding the research topics. The dissertation is concluded in section 12. Finally, references are listed and appendices are attached.

The content of the sections elaborating the scientific articles is limited to the main aspects of each contribution. Additional information is available in the corresponding publications. Regarding sections 2 to 10, each subsection follows an identical way to allow for a concise and unite structure. Figure 9 demonstrates this intra-section structure beginning with a short academic classification of the underlying research articles. Based on the research methodology applied, related approaches are presented in a reasonable manner. A problem description, containing motivation, related literature review, and investigated research question(s), takes place before the behavioristic study design (including hypotheses development) or mathematical model (including assumptions and notation) is outlined. The subsections 2.3, 6.3, and 7.3 also introduce a DSS. Subsequently, the results (and benchmarks in case of DSR approaches) are discussed while recommendations and generalizations are drawn. The final subsections highlight derived contributions, state limitations, and present future research opportunities of the introduced approaches.

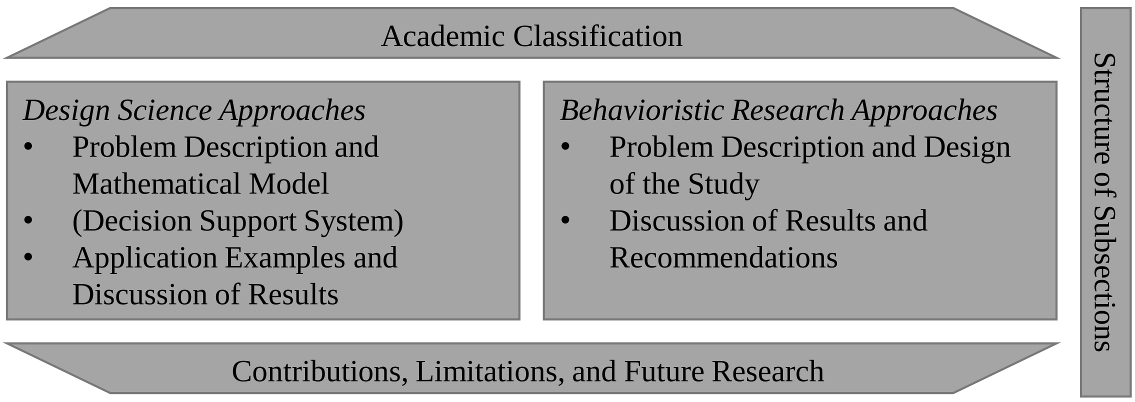


Figure 9. Structure of Subsections Regarding Scientific Approaches.

PART A: URBAN MOBILITY

<table>
<tr><td colspan="10">Physical Transport</td></tr>
<tr><td colspan="5">Passenger Transport</td><td colspan="5">Freight Transport</td></tr>
<tr><td colspan="2" rowspan="2">Private Passenger Transport</td><td colspan="6">Commercial Transport</td><td colspan="2" rowspan="2">Private Freight Transport</td></tr>
<tr><td colspan="2">Commercial Passenger Transport</td><td colspan="2">Commercial Service Transport</td><td colspan="2">Commercial Freight Transport</td></tr>
<tr><td colspan="4">Urban Mobility</td><td colspan="6">Urban Logistics</td></tr>
<tr><td colspan="10">Urban Transport</td></tr>
</table>

Figure 10. Classification of Transport Modes: Urban Mobility; Adapted from Arndt (2010).

"The reform of urban mobility systems is one of the biggest challenges confronting policymakers, stakeholders, and users today"

Lerner (2011:6)

"Reinforcing urban mobility while reducing congestion, accidents and pollution is a common challenge to all major cities."

European Commission (2019:1)

A Primer to Urban Mobility

Urban mobility denotes passenger movements within the city environment. As described by Arndt (2010), this includes both commercial and private trips. With the increasing mobility needs of city dwellers, current urban mobility systems are reaching their limits. Due to the multitude of described challenges, such as high emissions, poor air quality, fossil fuel dependency, traffic volume, and congestion together with increasing consciousness for environmental responsibility, the need for solutions tackling these issues is emerging (Chan and Shaheen, 2012). A possible starting point is the arisen sharing economy, as sharing goods or services reduces physical and immaterial inefficiencies. Regarding urban passenger transport, on-demand ride services depict an opportunity to individually share a car or a trip in different modes. These sharing concepts are characterized as new mobility services (NMS). Emerging technologies (e.g., digitalization, high-speed computing, location data, accurate sensors, wireless connectivity, and new usage-based pricing schemes) constitute as enabler for NMS (Spulber et al., 2016). In urban areas, NMS aim to shift mobility behavior towards a multimodal and less private vehicle-centric system. Based on the substitution of private vehicles, traffic density, travel costs, travel time, fuel consumption per person, and air pollution are reduced (Furuhata et al., 2013; Kuntzky et al., 2013). Emission-reducing aspects are further intensified if alternative vehicles are used. Compared to public transportation, NMS have advantages in terms of high flexibility, short waiting times, and easy payment methods (Rayle et al., 2016). Figure 11 gives an overview of different NMS including a brief explanation of the specific business model. In the following, the concepts of (station-based) carsharing and ridepooling are investigated in terms of optimization or customer acceptance.

New mobility service	**Description**
Carsharing: Station-based (business-to-consumer)	Users pay fees based on the period of use and/or distance for renting a car at fixed locations. The vehicles are owned by companies.
Carsharing: One-to-many (business-to-consumer)	Users pay fees based on the period of use and/or distance for renting a car, whereas differing pickup and drop off locations can be freely chosen within a defined operation area. The vehicles are owned by companies.
Carsharing: Peer-to-peer (consumer-to-consumer)	Cars are provided by private persons, who share their own vehicles with others on a rental basis. A company functions as intermediary between the two private peers, owners and users.
Carpooling & Ridesharing	A private vehicle is used by two or more individuals at the same time in the same car from and to similar destinations. The matching is organized by an intermediary company or by an informal system of the users.
Ridehailing	Determining the trip's start and end point, a passenger demands a transport service offered by companies or individuals.
Ridepooling & Shared ridehailing	Users hail a shuttle to designated pick-up points near their location. Passengers with similar routes are matched and transported together in one vehicle, owned by companies.

Figure 11. Evolution of New Mobility Services; Based on Clewlow and Mishra (2017).

Optimization of Station-Based Carsharing

Carsharing organizations offer their services in three main variations. Station-based carsharing services are differentiated between two-way carsharing, where users undertake round-trips and return the vehicle to the same station it was picked up at, and one-way carsharing, where different stations for pickup and arrival can be used. In contrast to that, free-floating carsharing services enable the user to pick up and drop off vehicles at any parking spot within the operation area (Weikl and Bogenberger, 2013). An overview of relating (dis-)advantages is presented in Sonneberg et al. (2020), taking the customer and provider side as well as the applicability of electric vehicles into account.

Research on carsharing related topics has increased over the past years. Literature overviews on the topic of carsharing are, for instance, presented by Degirmenci and Breitner (2014), Schmöller and Bogenberger (2020), and Webb (2019). Besides articles on the history and emergence of carsharing (e.g., Barth and Shaheen, 2002; Shaheen et al., 2009), investigations on taxonomies, business models, and success factors of carsharing are presented by Münzel et al. (2018) and Remane et al. (2016). Other articles analyze user characteristics as well as the environmental and social benefits of carsharing services (e.g., Clewlow, 2016; Juschten et al., 2019; Münzel et al., 2019). Nakamura et al. (2019) and Webb et al. (2019) investigate the users' adoption as well as willingness to switch from private vehicles to carsharing.

With respect to the optimization of carsharing, station-based concepts are divided into three interdependent planning stages (see Figure 12). The strategic perspective determines the long-term allocation of stations in terms of number, location, and size. The designation of vehicles to these stations is part of the tactical decision level in mid-term. Relocation procedures and pricing are part of operational strategies for the daily business. However, especially long- and mid-term activities influence each other and overlap to a certain extent.

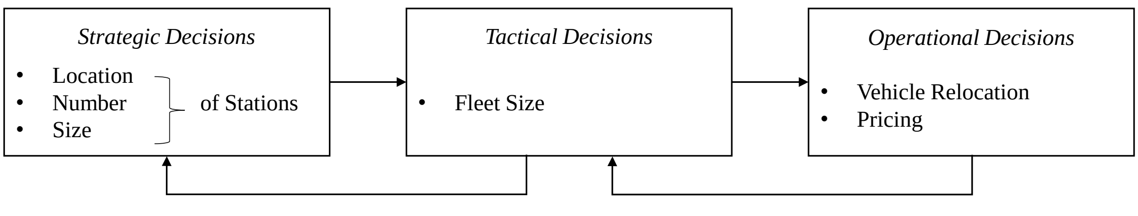


Figure 12. Planning Stages of Station-Based Carsharing; Based on Boyacı et al. (2015).

In this cumulative dissertation, all planning stages were tackled with respective optimization approaches to provide decision support for carsharing operators and planners as well as further relevant stakeholders. To proceed chronologically, section 2 refers to strategic carsharing network generation, section 3 investigates tactical fleet assignment, and section 4 contains an approach for carsharing revenue management at operative level.

For these approaches, the research methodology of DSR was used to create final artifacts for each decision level. Figure 13 illustrates the cycles applied to the topic of carsharing.

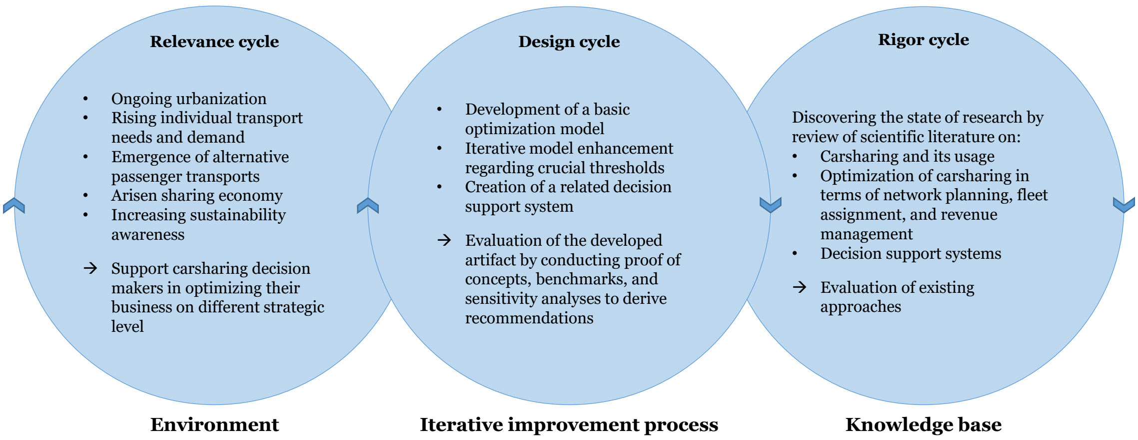


Figure 13. DSR-Cycles Applied to Carsharing; Adapted from Sonneberg et al. (2015).

Customer Acceptance of Ridepooling

In contrast to carsharing, ridepooling allows passengers not to drive themselves. Licensed drivers navigate a fleet of vehicles in cab-like manner trough urban areas. Via app, customers order a vehicle to a virtual station near their location. Passengers with similar routes are matched and transported together in one vehicle, which differentiates ridepooling from cab-services, ridesharing, or ridehailing (Clewlow and Mishra, 2017). The novel mobility concept of ridepooling is an upcoming research topic. While Gilibert and Ribas (2019) discuss the business model of ridepooling, König et al. (2018) elaborate critical success factors for ridepooling, namely walking distance, time of booking, price, shift of departure time, travel time, and information provision. Sanguinetti et al. (2019) discuss potentials of the service by applying automated vehicles and future implications for urban transport. The matching of customers in terms of optimization is part of articles by, e.g., Alonso-Mora et al. (2017), Bischoff et al. (2018), and Yu et al. (2019). By efficient matching of customers and well-utilized vehicles, significant reductions in terms of road traffic and saved emissions can theoretically be achieved.

However, ridepooling services are quite new and struggle with many prejudices. In its current utilization, many trips are conducted with only one customer (BerlKönig, 2019; Schaller, 2018; Schwaer and Meyer, 2019). Based on these customer figures, the services are far from reaching theoretical benefits, which can only be achieved with appropriate demand and usage. To address the low customer usage, acceptance analyses are necessary to investigate its reasons.

To do so, the TAM was used and adapted to the topic of ridepooling. Besides the already introduced main constructs of TAM (BI to use, ATU, PEOU, and PU), the adjacently briefly described constructs of TAM2 were examined (Venkatesh et al., 2012). Perceived compatibility (PC) is defined as the "degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters" (Lee et al., 2003:761). Perceived safety (PS) refers to the "degree to which an individual believes that using a system will affect his or her well-being" (Osswald et al., 2012:5). Subjective norm (SN) is the "person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein and Ajzen, 1975). The TAM2 was further extended with the succeeding two constructs. Price value (PV) is characterized as the "cognitive tradeoff between the perceived benefits of the applications and the monetary costs for using them" (Venkatesh et al., 2012:161). Environmental awareness (EA) refers to the "person's general understanding and awareness of environmental problems" and the resulting potential behavior change for a more sustainable way of life (Wang et al., 2020:403). Integrating these constructs, Figure 14 illustrates the examination of customer acceptance of ridepooling as part of section 5.

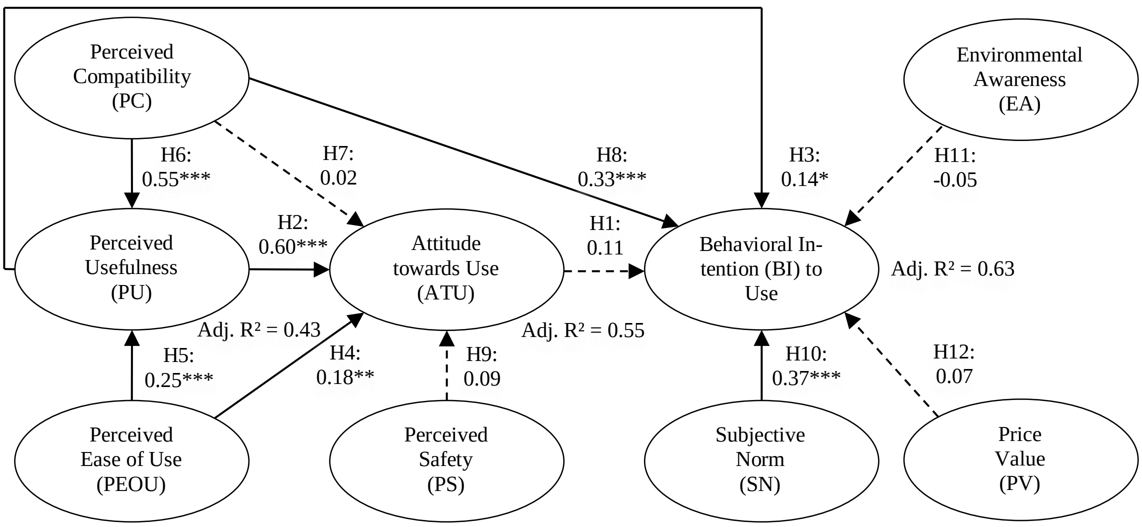


Figure 14. Structural Model and Relationship of Constructs; Based on Werth et al. (2020).

2. Network Optimization of Station-Based Carsharing

2.1. Academic Classification

This section deals with three consecutive research articles. The first article has the title "A Decision Support System for the Optimization of Electric Car Sharing Stations" and was contributed by Marc-Oliver Sonneberg, Kathrin Kühne, and Michael H. Breitner (Sonneberg et al., 2015 and Appendix A). The article was accepted and presented after one revision of a double-blind peer review (associate editor and two reviewers) within the track "Decision Analytics and Support" at the 36^{th} International Conference on Information Systems (ICIS) 2015 in Fort Worth (Texas, USA). With the conference theme "Exploring the Information Frontier", more than 1,000 academic IS professionals participated in presentations of about 180 completed research paper (ICIS, 2015). The ICIS, as the flagship conference of the Association for Information Systems (AIS), is described as "the most prestigious gathering of information systems academics and research-oriented practitioners in the world" (AIS, 2020a). The article finally was published in the corresponding proceedings of the 36^{th} ICIS, classified "A" in the JQ3 and also "A" in the WKWI rating. Following *Google Scholar*, the article is actually cited 17 times without self-citations.

Building on this article, a book chapter entitled "Station-based Electric Carsharing: A Decision Support System for Network Generation" was developed together with Michael H. Breitner (Sonneberg and Breitner, 2020 and Appendix K). The book called "Electric Vehicles in Shared Fleets: Mobility Management, Business Models and Decision Support Systems" edited by Degirmenci, Cerbe, and Pfau is forthcoming and will be published in 2020 by World Scientific, Singapore.

The above articles were significantly reworked concerning the model, its solution efficiency, the application examples, as well as the related discussions and recommendations. The resulting article named "Optimization of Station-Based Carsharing Networks: Increasing Sustainability through Heterogeneous Fleets and Emission Control" was a collaboration of by Marc-Oliver Sonneberg, Kathrin Kühne, and Michael H. Breitner (Sonneberg et al., 2020 and Appendix U). The article was published in the not rated IWI Discussion Paper Series and was not subject to a typical peer review. *With the exception of section 2.2, which is based on Sonneberg et al. (2015), the following section 2 is largely based on Sonneberg et al. (2020).*

2.2. Problem Description and Optimization Approach

The accessibility of carsharing stations is described as most relevant success factor of such services, thus the network planning is crucial for the long-term success of a carsharing organization (Stillwater et al., 2009). To satisfy existing customer demand within an urban area best, the stations should be as close as possible to the demand locations of customers. Scientific studies recommend a maximum distance of 750 meters or a 10 minutes walk as a critical value (Costain et al., 2012; Morency et al., 2008). In areas with lower demand, e.g. industrial parks, the question arises as to whether it is even worthwhile to open one or more stations there. Thus, an optimization approach is presented that does not have to satisfy the entire demand, but rather observe a definable service level.

Concepts for the strategic selection of carsharing stations are introduced by Awasthi et al. (2007) and Musso et al. (2012) who present approaches based on analytical processes using decision criteria weighting. El Fassi et al. (2012) develop a DSS that determines best expansion strategies for existing networks using discrete event simulation. The first optimization approach by Rickenberg et al. (2013) introduces a model to generate a carsharing network focusing on strategic optimization. With a focus on strategic and operative planning at the same time, Boyacı et al. (2015), Brandstätter et al. (2017), and Correia and Antunes (2012) neglect in some ways critical assumptions of network planning (e.g., heterogeneous fleets, different propulsion methods, emission limits, charging cycles for electric vehicles). Therefore, the developed approach focuses on the following research question:

How can an optimization model for strategic and tactical station-based carsharing be designed to maximize profit while applying a heterogeneous fleet and obtaining a maximum CO_2-threshold?

The developed optimization model maximizes the annual profit of a station-based carsharing organization offering two-way carsharing concerning the strategic station and tactical fleet planning. Poisson-distributed demand points are allocated within the investigation area. Possible carsharing stations with a corresponding limit of parking lots are spread over the investigation area. A threshold for the compliance of a maximum distance between demand and supply is implemented. Annual leasing costs for vehicles, parking lots, and stations are introduced containing all incidental expenses. Various propulsion methods, such as combustion engine, hybrid, or electric vehicles can be implemented.

Time for recharging is taken into account for electric vehicles, resulting in a maximum number of possible trips per day. To account for demand variations throughout the day, week, or month, peak and off-peaks are adjustable. In terms of a sustainable operation, a maximum CO_2-emission value over the entire fleet can be set. Before the mathematical model is introduced, the corresponding notation including sets, parameters, and decision variables is presented.

Sets:

$i = (1, \dots, I)$: *potential station location*
$j = (1, \dots, J)$: *demand location*
$p = (1, \dots, P)$: *propulsion method*
$w = (1, \dots, W)$: *time windows*

Parameters:

C_p: *leasing cost of charging infrastructure for propulsion method* p $[US\$\ p.a.]$
e_p: *energy price per propulsion method* p $[US\$/kwh]$ *or* $[US\$/l]$
f_p: *average energy consumption per propulsion method* p $[kwh/km]$ *or* $[l/km]$
k: *expected distance driven* $[km]$
L_i: *leasing cost of a parking lot at station* i $[US\$\ p.a.]$
n_i: *maximum number of lots at station* i $[\#]$
Q: *maximum distance between station* i *and demand location* j $[km]$
q_{ij}: *distance between station* i *and demand point* j $[km]$
r^{km}: *revenue for renting per distance* $[US\$/km]$
r^{min}: *revenue for renting per duration* $[US\$/min]$
S_i: *leasing cost of station* i $[US\$\ p.a.]$
t: *expected duration of a rent* $[min]$
U: *average maximum carbon dioxide emission per vehicle* $[g/km]$
u_p: *carbon dioxide emission per vehicle with propulsion method* p $[g/km]$
V_p: *leasing cost per vehicle with propulsion method* p $[US\$\ p.a.]$
Θ_{jw}: *Poisson distributed demand per time window* w *of location* j $[rents/time\ window]$
α: *considered demand period account for one year [#]*
β: *minimum level of service to satisfy* $[\#]$
γ_p: *possible trips per vehicle with propulsion method* p $[\#]$

Decision variables:

d_{ijpw}: *satisfied demand at station* i *for demand* j *of propulsion* p *at time window* w $[\#]$
v_{ip}: *number of vehicles with propulsion method* p *at station* i $[\#]$
y_i: 1, *if station is built;* 0, *else*
z_{ij}: 1, *if demand location* j *is served by station* i*;* 0, *else*

$$Max.F\,(\mathrm{v},y) = \overbrace{\alpha * \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{p=1}^{P}\sum_{w=1}^{W} d_{ijpw} * \left(\left(t * r^{min}\right) + \left(k * r^{km}\right)\right)}^{revenue\ [US\$\ p.a.]}$$

$$- \overbrace{\alpha * \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{p=1}^{P}\sum_{w=1}^{W} d_{ijpw} * \left(k * e_p * f_p\right)}^{variable\ costs\ [US\$\ p.a.]} \tag{1}$$

$$- \overbrace{\sum_{i=1}^{I}\sum_{p=1}^{P}\left(v_{ip} * \left(V_p + L_i + C_p\right) + y_i * S_i\right)}^{leasing\ costs\ [US\$\ p.a.]}$$

$$\sum_{i=1}^{I} z_{ij} \geq 1 \qquad \forall\, j, w \tag{2}$$

$$y_i \geq z_{ij} \qquad \forall\, i, j, w \tag{3}$$

$$\sum_{i=1}^{I}\sum_{p=1}^{P} d_{ijpw} \leq \Theta_{jw} \qquad \forall\, j, w \tag{4}$$

$$\sum_{p=1}^{P} d_{ijpw} \leq z_{ij} * \Theta_{jw} \qquad \forall\, i, j, w \tag{5}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{p=1}^{P} d_{ijpw} \bigg/ \sum_{j=1}^{J} \Theta_{jw} \geq \beta \qquad \forall\, w \tag{6}$$

$$v_{ip} * \gamma_p \geq \sum_{j=1}^{J} d_{ijpw} \qquad \forall\, i, p, w \tag{7}$$

$$\sum_{p=1}^{P} v_{ip} \leq n_i * y_i \qquad \forall\, i \tag{8}$$

$$q_{ij} * z_{ij} \leq Q \qquad \forall\, i, j \tag{9}$$

$$\sum_{i=1}^{I}\sum_{p=1}^{P} v_{ip} * u_p \bigg/ \sum_{i=1}^{I}\sum_{p=1}^{P} v_{ip} \leq U \tag{10}$$

$$y_i \in \{0, 1\} \qquad \forall\, i \tag{11}$$

$$z_{ij} \in \{0, 1\} \qquad \forall\, i, j \tag{12}$$

$$v_{ip}, d_{ijpw} \geq 0 \qquad \forall\, i, j, p, w \tag{13}$$

The objective function (1) maximizes the annual profit of a carsharing organization by calculating the revenues and subtracting the resulting variable as well as leasing costs. Constraints (2) to (3) are responsible for the establishment of stations and constitutional assignments, while constraints (4) to (7) guarantee the demand satisfaction by creation of resulting stations and vehicles. The adherence of threshold variables (parking lot, distance, and emission limit) are expressed in constraints (8) to (10). Constraints (11), (12), and (13) set the specific value range of the decision variables of the mixed integer linear problem (MILP).

2.3. Decision Support System

In addition to the developed mathematical model, a Java-based DSS is constructed to enable decision support for finding optimal locations and sizes of carsharing stations as well as the assigned fleet. The DSS combines several applications together with the optimization model. Due to easy usability, it allows decision makers to solve their own scenarios without optimization knowledge. With the dataset imported and parameters selected, the DSS solves the equations of the underlying model and provides corresponding results. Figure 15 illustrates the dataflow of the DSS.

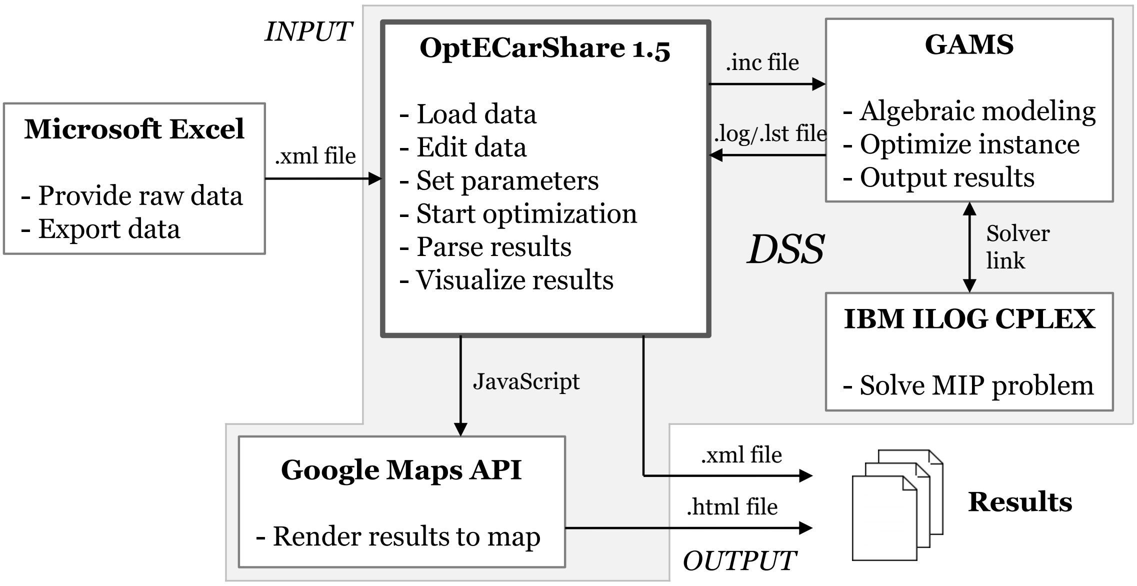


Figure 15. Dataflow of the DSS; Based on Sonneberg et al. (2015).

Additionally, Figure 16 provides an overview of the graphical user interface (GUI) of the so-called DSS *OptECarShare 1.5*. In the main GUI, the dataset and relevant parameters can be set. After all inputs entered, the process begins by clicking "Optimize". An opening window informs the user about the optimization progress and presents the results in terms of established stations and vehicle selection. By triggering the button "Visualize Results", the browser displays the resulting optimal carsharing network on a map.

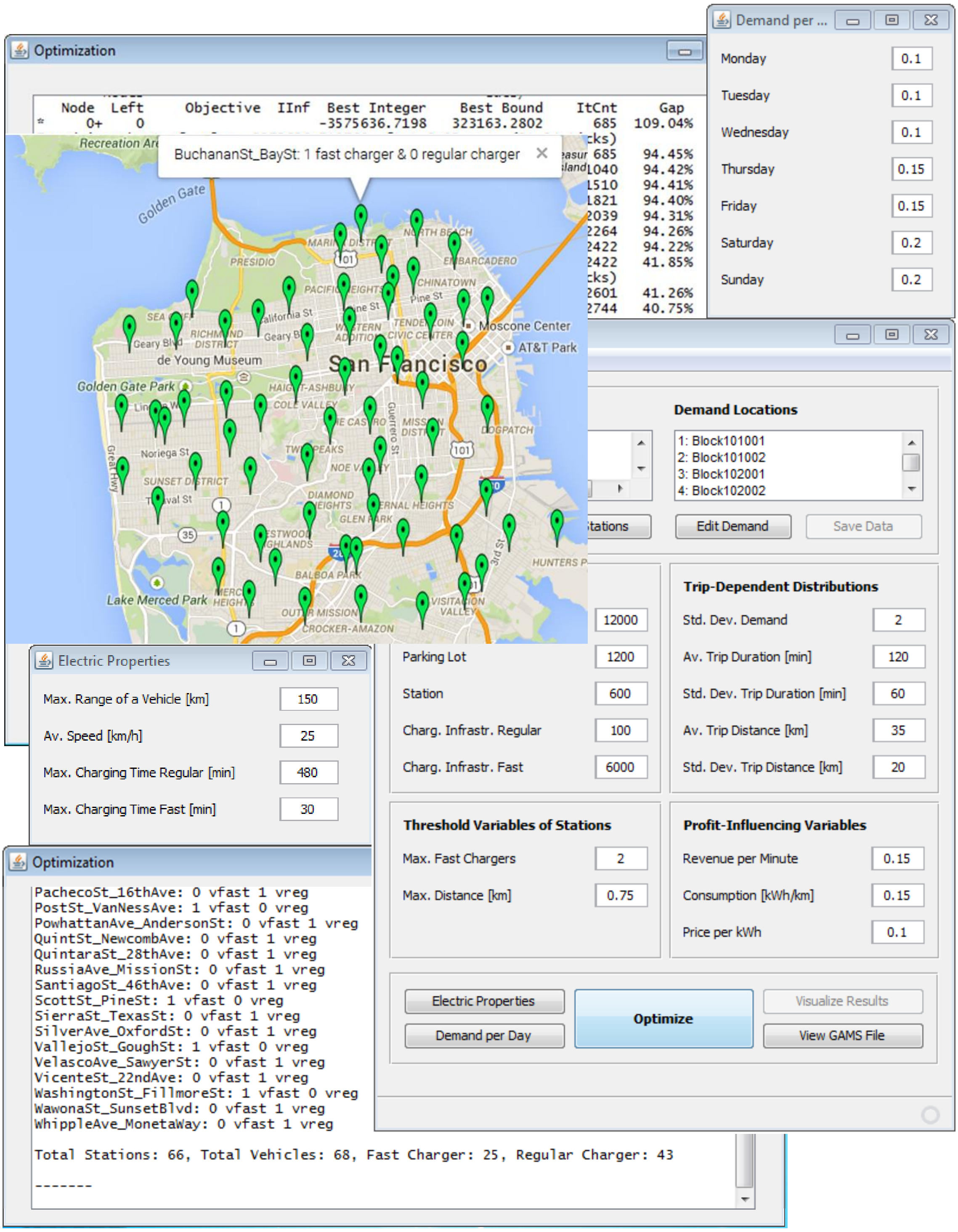


Figure 16. Design and Results Presentation of the DSS; Based on Sonneberg et al. (2015).

2.4. Application Example and Discussion of Results

To show the applicability of our approach, the DSS and the underlying model are validated by varying parameters ceteris paribus in several calculation examples. These benchmarks are conducted for the city of San Francisco using the software *General Algebraic Modeling System* (*GAMS*) (v. 24.5.6) together with the solver *IBM ILOG CPLEX* (v. 12.6.2). Based on existing districts of San Francisco, the city was grouped into several clusters. With the possibility of a heterogeneous fleet (petrol and electric vehicles), a maximum of one kilometer between stations and demand locations, an average CO_2-threshold of 75 g/km, and a service level of 98% to be satisfied, the following Table 3 illustrates variations of the underlying investigation area.

Table 3. Benchmarks on the Size of the Investigation Area; Based on Sonneberg et al. (2020).

Clustered districts [3% gap]	Profit [US$]	# Stations	# Vehicles		Av. CO_2-emission [g/km]	Demand satisfaction [%]	Computing time in total [mm:ss]	Calculation time [mm:ss]
			Petrol	Electric				
Cluster 1	165,567	5	4	3	72.57	99.7	00:10	00:05
Cluster 2	337,500	8	8	6	72.57	99.8	01:06	00:50
Cluster 3	611,785	18	15	11	73.27	99.8	08:15	04:06
Cluster 4	665,355	27	21	15	74.08	98.9	16:54	08:38
Cluster 5	629,405	36	25	18	73.83	99.6	18:49	10:06

Cluster 1 only contains the central districts with the highest estimated demand levels for carsharing whereas Cluster 5 represents the entire city of San Francisco. As visible, the profit increases with widening the investigation areas. In cluster 5, stations also need to be built for areas with lower demand levels, which implies a decrease in profit compared to cluster 4. This is due to the estimated demand and the resulting lower utilization rate of vehicles in the additional districts. As result, a network of stations and vehicles is more expensive than the profit to be achieved here.

Further, the impact of the variation of maximum allowed distance (0.5 km, 0.75 km, 1 km, 1.25 km, and 1.5 km) between a demand and its assigned station location is demonstrated in Figure 17. Cluster 4 is chosen due to its most profitable characteristics (see Table 3). For each distance, the corresponding annual profit as well as number of stations and vehicles are shown in the left part of Figure 17; the right part compares profit and demand satisfaction.

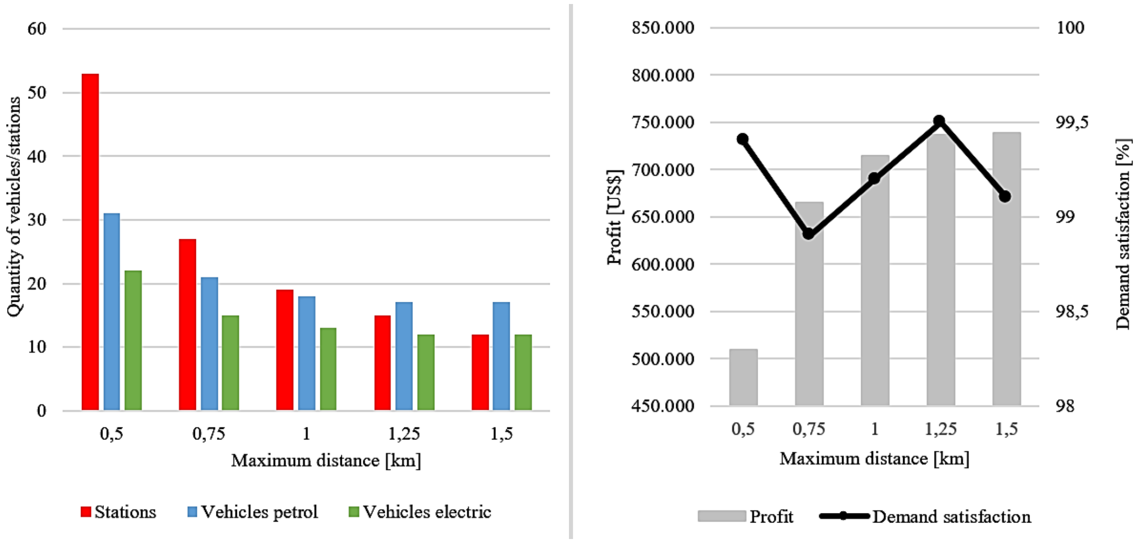


Figure 17. Variation of the Maximum Distance; Based on Sonneberg et al. (2020).

By increasing the maximum distance, less vehicles and established stations can be observed while demand satisfaction does not vary significantly. With shorter allowed distances, more stations and vehicles are required. Low occupancy rates of vehicles result in a reduction of profit. In terms of profit in general, a network with a maximum distance of 1.5 km reveal a 50% higher yield compared to the 0.5 km case. However, larger distances to reach the next station can negatively influence the customer satisfaction. By varying several other parameters in further scenarios, generalizations can be derived. Table 4 summarizes the impacts on network, fleet, and profit carved out.

Table 4. Generalizations regarding Stations, Vehicles, and Profit; Based on Sonneberg et al. (2020).

Impact (ceteris paribus) of … on	**Number of stations**	**Number of vehicles**			**Profit**
		In total	**Electric**	**Petrol**	
Costs for stations ↑	→	→	→	→	↓
Costs for parking lots ↑	→	→	→	→	↓
Costs for electric vehicles ↑	→	→	↓	↑	↓
Costs for petrol vehicles ↑	→	→	↑	↓	↓
Demand ↑	↑	↑	↑	↑	↑
CO_2-emission limit ↓	→	→	↑	↓	↓
Price per kWh ↑	→	→	↓	↑	↓
Price per liter petrol ↑	→	→	↑	↓	↓
Max. distance ↑	↓	↓	↓	↓	↑

The network structure is not influenced by a cost increase of stations or parking lots, nonetheless, profit decreases. Rising leasing costs for a specific vehicle type also has no effect on the number of stations, but reduces the number of this vehicle type and increases the number of vehicles with unchanged costs. An increase in demand has a cumulative impact on all the above variables. A lower average CO_2-limit will not change the number of stations and vehicles, while the number of electric vehicles will heighten and the number of petrol-powered vehicles and profit will decrease. Any raise in petrol or energy prices has a similar effect on the costs of each vehicle type. Further, a higher maximum distance between supply and demand points reduces the number of stations, surges profit, and decreases the number of both vehicle types.

2.5. Contributions, Limitations, and Future Research

With the introduction of a MILP, the complex task of station and fleet planning respective optimization for station-based carsharing services is supported. Taking heterogeneous fleets and ecological sustainability into account, the superordinate goal was maximizing the annual profit. The model and DSS were evaluated by using San Francisco as an application example to derive practical implications. Slight parameter adjustments can have a significant impact on the optimal deployment of the carsharing network and its utilization. Thus, the approach contributes to station-based carsharing as a sustainable mobility concept for private trips and carsharing planning and optimization literature. The mathematical model and the DSS as contributions address the existing lack of solution-oriented research within the domain of Green IS (Malhotra et al., 2014; Gholami et al., 2016).

Despite certain limitations, it was possible to verify the applicability and usefulness of the optimization model and the DSS. Since demand is the most important success factor, additional information about the typical carsharer could further validate and improve our approach. Further consideration should be drawn to the placement of stations and especially the installation of charging infrastructures, which cannot be established everywhere as certain conditions have to be met. The optimization model itself and respectively the DSS could be refined by adding aspects not yet considered, such as the implementation of multi-mobility constraints, demand-driven pricing, or a one-way option including relocation procedures. To obtain even faster results, a heuristic solution approach should be developed. Especially the focus on round-trip carsharing is a major concern, as today's urban carsharing organizations most often offer station-based one-way or even free-floating concepts. Those concepts require intense planning of relocation procedures to counteract imbalances of the whole service as well as a thorough investigation regarding the implementation of charging cycles when using electric vehicles.

3. Fleet Optimization of Station-Based Carsharing

3.1. Academic Classification

In this section, the research article "Ecological & Profitable Carsharing Business: Emission Limits & Heterogeneous Fleets" is discussed (Kühne et al., 2017 and Appendix F). Kathrin Kühne, Marc-Oliver Sonneberg, and Michael H. Breitner contributed to the work, which was submitted to the 25th European Conference on Information Systems (ECIS) 2017 in Guimarães, Portugal. The comments of two reviewers (rating both four out of five) and the track chair (rating 5: definitively accept) resulted in the decision conditional accept. After minor revisions, the paper was finally accepted for presentation at the conference and publication within the proceedings of ECIS. The article was part of the theme track of the ECIS 2017 "Information Systems for a smart, sustainable and inclusive world" which was also the conference theme. The ECIS is a conference of the AIS describing it as the leading IS conference dedicated to the European region (AIS, 2019). In the JQ3 rating, the ECIS proceedings are graded "B", within the WKWI rating it is rated "A". *The following section 3 is largely based on Kühne et al. (2017).*

3.2. Problem Description and Optimization Approach

The accessibility and availability of vehicles in station-based two-way carsharing is described as one of the most significant factors for reaching profits, while meeting customers' demands (Boyacı et al., 2015, Münzel et al., 2018). Focusing on fleet optimization, some articles explicitly address the tactical decision level. Rhee et al. (2014) provide assistance for fleet dimensions by help of a scenario analysis technique called discrete event simulation. An approach for optimal allocation of trips to vehicles is presented by Costain et al. (2012) to minimize the number of required carsharing vehicles. Other approaches concentrate on several planning stages (Boyacı, et al., 2015; Nourinejad and Roorda, 2014). This results in a lack of required depth in terms of tactical fleet optimization. Hence, our approach focuses strictly on optimization of tactical vehicle distribution of a station-based carsharing system. With an existing network fixed in number, location, and size of stations, an optimization approach for tactical fleet planning was developed with the objective of profit maximization. The underlying research question was:

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

Regarding the assumptions of the developed model, one demand represents one trip, which does not have to be satisfied completely. For each unsatisfied demand of a trip, penalty costs incur and increase quadratically to guarantee high service levels and customer satisfaction. Time frames are used to illustrate peak and off-peak times in the course of a day and a month. With different vehicle classes and propulsion methods implemented, recharging processes in case of electric or hybrid vehicles are considered. Monthly leasing costs for charging infrastructures, vehicles, and parking lots incur. To react on monthly fluctuations, parking lots, charging infrastructures, and vehicles can be leased differentially. Threshold in terms of CO_2-emissions and possible parking lots at existing stations are integrated within the approach. The revenue for renting a vehicle is charged on a time and distance basis differentiated by the vehicle class.

Before presenting the mathematical model, sets, parameters, and decision variables used are introduced in the following:

Sets:

$c = (1, \ldots, C)$: *vehicle class*

$f = (1, \ldots, F)$: *time frame*

$i = (1, \ldots, I)$: *location of station*

$j = (1, \ldots, J)$: *demand location*

$t = (1, \ldots, T)$: *vehicle type (in terms of propulsion mode)*

Parameters:

co_{ct}: $CO_2 -$ *emissions of a vehicle* $[g/km]$

$comax$: *maximum average admissible emission of* CO_2 $[g/km]$

d_{cif}: *Poisson distributed demand* $[\#\ trips/\ time\ frame]$

dd: *normal distributed distance driven per trip* $[km]$

dis_{ji}: *distance between demand location and station* $[km]$

$dismax$: *maximum distance between demand location and assigned station* $[km]$

dur_f: *duration of a time frame* $[min]$

ec_{ct}: *average energy consumption* $[l/km\ or\ kwh/km]$

ed: *average duration of a trip* $[min]$

ek: *distance of a trip* $[km]$

ep_t: *average price for energy* $[US\$/l\ or\ US\$/kWh]$

g_f: *factor of time frame* $[\#]$

l_{ft}: *leasing cost of charging infrastructure* $[US\$/month]$

l_{si}: *fixed cost of a station* $[US\$/month]$

lp: *leasing cost of a parking lot* $[US\$/month]$

lv_{ct}: $leasing\ cost\ of\ vehicle\ [US\$/month]$

$maxp_i$: $maximum\ number\ of\ parking\ lots\ at\ a\ station\ [\#]$

min: $normal\ distribution\ of\ duration\ of\ a\ trip\ [min]$

n_t: $number\ of\ possible\ trips\ of\ a\ vehicle\ type\ [\#]$

p_{cj}: $Poisson\ distributed\ demand\ [\#]$

$revd_c$: $revenue\ for\ renting\ a\ vehicle\ [US\$/km]$

$revm_c$: $revenue\ for\ renting\ a\ vehicle\ [US\$/min]$

sd: $standard\ deviation\ of\ duration\ of\ a\ trip\ [min]$

sdk: $standard\ deviation\ of\ distance\ of\ a\ trip\ [km]$

Decision Variables:

$s_{cift} \geq 0$: $number\ of\ satisfied\ demand$

$u_{cift} \geq 0$: $number\ of\ unsatisfied\ demand$

$v_{cit} \geq 0$: $number\ of\ vehicles$

$z_{cji} \in \{0,1\}$: $1, if\ demand\ is\ assigned\ to\ a\ station; 0, else$

Based on this notation, the following MILP for carsharing fleet optimization results:

$$\begin{aligned} \text{Max}\, Z(s,u,v) = & \sum_{c=1}^{k}\sum_{i=1}^{m}\sum_{f=1}^{l}\sum_{t=1}^{o} s_{cift} * (min * revm_c + dd * revd_c) \\ & - \sum_{c=1}^{k}\sum_{i=1}^{m}\sum_{f=1}^{l}\sum_{t=1}^{o} s_{cift} * (dd * ec_{ct} * ep_t) \\ & - \sum_{c=1}^{k}\sum_{i=1}^{m}\sum_{f=1}^{l}\sum_{t=1}^{o} u_{cift}^2 - \sum_{c=1}^{k}\sum_{t=1}^{o}\sum_{i=1}^{m} (lv_{ct} + lf_t + lp) * v_{cti} - \sum_{i=1}^{m} ls_i \end{aligned} \quad (1)$$

$$\sum_{i=1}^{m} z_{cij} = 1 \qquad \forall\, c, j \quad (2)$$

$$\sum_{c=1}^{k}\sum_{j=1}^{n} z_{cji} \geq 1 \qquad \forall\, i \quad (3)$$

$$\sum_{c=1}^{k}\sum_{j=1}^{n} v_{cti} \geq 1 \qquad \forall\, i \quad (4)$$

$$\sum_{c=1}^{k}\sum_{t=1}^{o} v_{cti} \leq maxp_i \qquad \forall\, i \quad (5)$$

$$dis_{ji} * z_{cji} \leq dismax \qquad \forall\, c, j, i \quad (6)$$

$$\sum_{j=1}^{n} d_{cif} * z_{cji} = \sum_{t=1}^{o} s_{cift} + u_{cif} \qquad \forall\, c, i, f \quad (7)$$

$$d_{cjf} = g_f * p_{cj} \qquad \forall\, c, j, f \tag{8}$$

$$s_{cift} \leq v_{cti} * n_t \qquad \forall\, c, i, f, t \tag{9}$$

$$\sum_{c=1}^{k}\sum_{t=1}^{o}\sum_{i=1}^{m} v_{cti} * co_{ct} \Bigg/ \sum_{c=1}^{k}\sum_{t=1}^{o}\sum_{i=1}^{m} v_{cti} \leq comax \tag{10}$$

$$s_{cift};\ u_{cif};\ v_{cti}\ \geq 0 \qquad \forall\, c, i, f, t \tag{11}$$

$$z_{cji} \in \{0, 1\} \qquad \forall\, \mathrm{c}, j, i \tag{12}$$

The objective function (1) maximizes the monthly profit of a carsharing organization by calculating the trip revenues subtracting variable distance costs, penalty costs for unsatisfied demands, and leasing costs of pre-established stations as well as built vehicles, parking lots, and charging infrastructures, if required. The correct assignment of vehicles and parking lots to stations are part of constraints (2) to (4). Constraints (5), (6), and (10) denote the adjustable thresholds in terms of parking lot availability at stations, maximum distance between demand and supply locations, and CO_2-emissions. The demand allocation to vehicles within corresponding time frames is expressed by constraints (7) to (9). Equations (11) and (12) constitute the value range of the decision variables.

3.3. Application Example and Discussion of Results

Using the strategic optimization model of Sonneberg et al. (2015), a basic scenario for existing carsharing stations with 55 carsharing stations in total is assumed. To allow for fleet heterogeneity, three vehicles types (gas, hybrid, and electric) in two different classes (small and medium) are considered. With a maximum distance of 0.75 km between demand and assigned station locations, varying CO_2-emissions (0, 75, 150 g/km) as well as the demand levels (low and high) are applied. To account for fluctuating demand in the course of the month and the day, the demand is subdivided into time frames. By choosing a duration of six hours for each time frame per day, 112 time frames result for the investigation of a month (consisting of 28 days). Using a standard notebook (Intel Core i5, 2.5 GHz CPU, 16 GB RAM) and *GAMS 24.5.6* with the solver *IBM ILOG CPLEX 12.6.2*, the following results were obtained with a preset gap of 3%. Besides profit, Table 5 illustrates the number of each vehicle type t (1=gas; 2=hybrid; 3=electric) and class (small; medium), total number of vehicles, average CO_2-emission, percentages of satisfied trips of small and medium classes, and percentage of total demand satisfaction.

Table 5. Variations of CO_2-Emission Limits and Demand Profiles; Based on Kühne et al. (2017).

	CO_2-Emission Limit	Profit in US$	Small			Medium			# Total Vehicles	Av. CO_2 in g/km	Demand Satisfaction in %		
			# t1	# t2	# t3	# t1	# t2	# t3			Small	Medium	Total
Demand Scenario 1 Low: 2.5%	0g/km	-39,952	0	0	52	0	0	3	55	0	99.52	95.71	99.14
	75g/km	-16,026	1	51	0	0	2	1	55	75	99.52	95.71	99.14
	150g/km	-13,063	52	0	0	3	0	0	55	122	99.52	95.71	99.14
Demand Scenario 2 High: 7.5%	0g/km	25,096	0	0	49	0	0	10	59	0	90.99	73.26	87.61
	75g/km	49,738	2	51	3	0	14	1	71	75	94.61	88.27	93.40
	150g/km	52,423	55	3	0	8	9	0	75	118	95.52	89.56	94.38

With regard to demand scenario 1, it is notable that the profit for all three CO_2-emission limits considered is negative. The higher the CO_2-emission limit is, the lower the loss. The total number of vehicles remains the same in all low demand scenarios, but due to the limitation emissions, only more expensive electric vehicles with appropriate charging infrastructure are used in the 0g/km scenario. The satisfaction rate of demand does not change for the three CO_2-limits considered. Due to penalties for unsatisfied trip demands, most trips are met to minimize losses. In all low demand scenarios, it is therefore not worth running a carsharing business.

In scenario 2 with higher demand, the carsharing organization will achieve a positive profit irrespective of the CO_2-limit. Even with a limit of 0g/km and a homogeneous electric fleet. If the CO_2-limit value is set higher, the profit will increase, as gas and hybrid vehicles are cheaper than electric ones. With rising emission levels, demand satisfaction increases. The utilization rate may be lower for electric and hybrid vehicles, as they require charging cycles that reduce the number of possible trips. At a low emission level, it is therefore more profitable not to satisfy a certain demand instead of providing more electric vehicles.

Comparing both demand scenarios, the total number of vehicles in demand scenario 2 is higher because there is more demand, yet the demand satisfaction is still lower. The carsharing organization can generate more revenue and thus the less profitable demand is not weighted as highly as in scenario 1. Under both scenarios, the demand satisfaction rate for small vehicles is higher because they are cheaper than medium class vehicles. In summary, lower CO_2-thresholds lead to higher costs and in result to a reduction in carsharing organization profits. In absence of subsidies from an economic point of view, it is not advisable to include electric vehicles in the carsharing fleet, as they are not yet profitable. However, electric vehicles and in some cases hybrid vehicles are useful for image and prestige reasons or to meet legal requirements for CO_2-emission limits.

3.4. Contributions, Limitations, and Future Research

The article provides decision support for station-based carsharing organizations on tactical decision level determining the composition and size of a heterogeneous carsharing fleet under consideration of emission limits with time-dependent demand. By performing various benchmarks, influences of key input variables on the results were obtained. Parameters can be adapted for any city worldwide by using predicted or experienced demand values. With the developed model, relevant decision makers are supported in their response to monthly demand fluctuations while taking into account customer satisfaction, sustainability, and profitability. Urban planners, city authorities, or governments are assisted in setting appropriate CO_2-emission limits to ensure that carsharing organizations include alternative propulsion methods in their fleets. The model can also aid to define subsidies to promote environmental sustainability while ensuring that the carsharing organization is profitable. Our solution-oriented artifact is positioned within the domain of Green IS and focuses on green transportation issues enabling improved sustainability through easy and self-explanatory use of tactical optimization for carsharing services (Malhotra et al., 2014; Gholami et al., 2016).

However, the model is limited due to various assumptions and simplifications. The time-dependent demand plays a decisive role as selected peaks and off-peaks are still an estimate. Therefore, the Poisson distribution was chosen as this probability distribution is suitable for modeling the frequency of an event over a period of time. Nevertheless, queuing theory could be considered in future research with a focus on Markov chains. Another limitation of our model refers to the assumption that time frames cannot overlap. If overlapping periods are taken into account in future research, the chosen duration of six hours must be reconsidered. The shorter the time windows, the more accurate is the modeling of demand fluctuations over the course of the day. A further aspect that can be discussed as a limitation is that the model only considers station-based carsharing in two-way mode. Electric vehicles in particular represent challenges (e.g., the implementation of a charging infrastructure at each station) for both one-way and free-floating modes. In addition to required charging infrastructures and extra parking spaces to be defined, relocation techniques must be incorporated to eliminate possible vehicle imbalances. Finally, a validation of the approach with a real field test should be carried out.

4. Revenue Management of Station-Based Carsharing

4.1. Academic Classification

The research article "Revenue Management Meets Carsharing: Operating the Daily Business" is introduced in section 4. It is a collaboration of Justine Broihan, Max Möller, Kathrin Kühne, Marc-Oliver Sonneberg, and Michael H. Breitner (Broihan et al., 2018 and Appendix G). After having presented corresponding slides at the 27th International Conference on Operations Research (ICOR) 2016 with the conference theme "Analytical Decision Making", we were invited to submit a full research article to the conference proceedings. With an average rating of four out of five in various evaluation categories, only minor changes were necessary for final acceptance. With about approximately 700 international practitioners and academics from mathematics, computer science, business, and economics, the ICOR is the largest European conference in this field (ICOR, 2016). The proceedings of the ICOR are rated "D" within the JQ3. *The following section 4 is largely based on Broihan et al. (2018).*

4.2. Problem Description and Mathematical Model

In recent years, the number of cities equipped organizational carsharing services has significantly increased. Thus, providers are dealing with an exponentially growing number of customers worldwide. As a result, rising vehicle utilization is making providers think about revenue management elements. Revenue management practices are considered as an essential tool for the operational success of a company (Bitran and Caldentey, 2004). When focusing on station-based carsharing concepts, these are typically based on (short) advance bookings and ideally suited for the application of demand-side management approaches. By managing demand, organizations can optimize their revenues by accepting or rejecting certain trips. While demand management concepts are available, e.g., for the car rental industry, carsharing related research lacks such a focus (Guerriero and Olivito, 2014; Hänsel et al., 2012). These car rental approaches does not focus on the combination of operators' risk aversion, customer satisfaction, and demand uncertainty, which are seen as crucial aspects for the carsharing businesses. As those elements are addressed in a hotel context, the corresponding optimization model of Lai and Ng (2005) was adapted to the context of carsharing to support its revenue management by investigating the following research questions:

How can revenue management practices be adapted to carsharing concepts? and *How do the decision variables change, if local emission prerequisites vary?*

To answer these research questions, the assumptions of the mathematical model for demand-side related revenue management optimization have to be mentioned. The developed model considers different time frames with an interval duration of three hours resulting in eight time frames per day. The maximum trip duration is limited to 24 hours, overnight bookings are split into two reservations. Customers are able to make a reservation in advance. Started time frames must be paid entirely by the customer. Every time frame can be subject to individual pricing. All vehicles are available at the start and the end of the observation period. With the help of the following notations, the subsequent mathematical model is developed.

Sets:

$i = (1, \dots, T-1)\colon start\ of\ rental\ (time\ frame)$

$j = (2, \dots, T)\colon end\ of\ rental\ (time\ frame)$

$k = (2, \dots, T-1)\colon any\ point\ in\ time\ (time\ frame)$

$s = (1, \dots, S)\colon scenarios$

$t = (1, \dots, N)\colon vehicle\ types$

$z = (1, \dots, Z)\colon stations$

Parameters:

$C_{z,t}\colon capacity\ at\ station\ z\ of\ vehicle\ type\ t$

$CO_{max}\colon maximum\ permitted\ CO_2 - emission$

$E_t\colon CO_2 - emission\ of\ vehicle\ typet\ per\ time\ frame$

$\lambda\colon risk\ aversion\ of\ management\ (Trade - off\ factor)$

$p_s\colon probability\ of\ scenario\ s$

$R_{i,j}^s\colon revenue\ for\ a\ trip\ with\ start\ at\ frame\ i\ and\ end\ at\ frame\ j\ in\ scenario\ s$

$U_{i,j,z}^s\colon demand\ for\ a\ trip\ starting\ at\ station\ z\ in\ frame\ i\ and\ ending\ in\ frame\ j\ in\ scenario\ s$

$w_{i,j}\colon weighting\ parameter\ for\ a\ trip\ stating\ at\ frame\ i\ ending\ at\ frame\ j$

Decision Variables:

$x_{i,j,z,t}\colon number\ of\ accepted\ reservations\ starting\ at\ z\ in\ frame\ i\ ending\ in\ frame\ j\ with\ type\ t$

With the notation introduced, the following mathematical model is developed as a mixed integer non-linear problem (MINLP):

$$
\begin{aligned}
\text{Max} = \sum_{s=1}^{S}\left(p_s * \sum_{i=1}^{T-1}\sum_{J=i+1}^{T}\sum_{z=1}^{Z}\sum_{t=1}^{N}(j-i) * R_{i,j}^{s} * x_{i,j,z,t}\right) \\
- \lambda \sum_{s=1}^{S}\left[p_s \left|\sum_{i=1}^{T-1}\sum_{J=i+1}^{T}\sum_{z=1}^{Z}\sum_{t=1}^{N}(j-i) * R_{i,j}^{s} * x_{i,j,z,t}\right.\right. \\
\left.\left. - \sum_{s=1}^{S}\left(p_s * \sum_{i=1}^{T-1}\sum_{J=i+1}^{T}\sum_{z=1}^{Z}\sum_{t=1}^{N}(j-i) * R_{i,j}^{s} * x_{i,j,z,t}\right)\right|\right] \\
- \sum_{s=1}^{S}\left(p_s * \sum_{i=1}^{T-1}\sum_{J=i+1}^{T}\sum_{z=1}^{Z}\sum_{t=1}^{N} w_{i,j}\left|U_{i,j,z}^{s} - x_{i,j,z,t}\right|\right)
\end{aligned}
\tag{1}
$$

$$\sum_{i=1}^{k-1}\sum_{j=k+1}^{T} x_{i,j,z,t} + \sum_{j=k+1}^{T} x_{k,j,z,t} \leq C_{z,t} \qquad \forall\, k,z,t \tag{2}$$

$$\sum_{j=2}^{T} x_{1,j,z,t} \leq C_{z,t} \qquad \forall\, z,t \tag{3}$$

$$\sum_{t=1}^{N} x_{i,j,z,t} \leq max\{U_{i,j,z}^{s}\} \qquad \forall\, i,j,z \tag{4}$$

$$\frac{\sum_{i=1}^{T-1}\sum_{j=i+1}^{T}\sum_{z=1}^{Z}\sum_{t=1}^{N}(j-i) * E_t * x_{i,j,z,t}}{\sum_{i=1}^{T-1}\sum_{j=i+1}^{T}\sum_{z=1}^{Z}\sum_{t=1}^{N}(j-i) * x_{i,j,z,t}} \leq CO_{max} \tag{5}$$

$$\sum_{i=1}^{T-1}\sum_{z=1}^{Z} x_{i,8,z,2} = 0 \tag{6}$$

$$x_{i,j,z,t} \geq 0 \qquad \forall\, i,j,z,t \tag{7}$$

$$1 \leq i < j \leq T \qquad \forall\, s \in \Omega \tag{8}$$

The objective function (1) optimizes the daily revenue of the carsharing organization by maximizing the expected revenue of a given scenario and subtracting the average absolute deviation of the revenue as well as the absolute deviation of the demand. The observance of supply and demand by adherence to time frames is observed by the constraints (2) to (4). The emission threshold is part of the constraint (5). The limitation (6) ensures the availability of all vehicles at the beginning of an operating day. Constraints (7) and (8) restrict the value range of the decision variables.

4.3. Application Example and Discussion of Results

The following application example and benchmarks are calculated by help of the modeling software *GAMS 24.7.1* in combination with the solver *COUENNE 0.5*. The gap is set to 0%. Figure 18 presents the number of accepted bookings for each combination of start time and rental end for station 1 and 2 in relation to the type of propulsion used (diesel and electric). A short example illustrates the structure of the table: for station 1 in time frame 1, seven diesel and 13 electric vehicles are rented. Three of the diesel and eleven of the electric vehicles were returned at time frame 2. Therefore, 224 rented time frames are served by diesel-powered vehicles and 115 by electric vehicles, giving a total of 339. 184 rented time frames are operated at station 1, the remaining 155 at station 2. Within this scenario, the objective function value amounts to 6,832 €. Comparing this optimized procedure with a first-in-first-serve approach with demand-side management, the developed model increases the objection function value by more than 49% (2,272 €) per day. Since profitable journeys have priority over less profitable or short-term reservations, the utilization of the vehicles is optimized.

	Station 1														Station 2													
	Diesel							Electric							Diesel							Electric						
Ending Time Frame / Starting Time Frame	2	3	4	5	6	7	8	2	3	4	5	6	7	8	2	3	4	5	6	7	8	2	3	4	5	6	7	8
1	3	3	1	-	-	-	-	11	2	-	-	-	-	-	6	4	2	-	-	-	-	10	-	-	-	-	-	-
2		3	-	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-
3			-	13	-	-	5			-	-	-	11	-			-	7	-	-	7			-	-	-	10	-
4				-	-	-	6				-	-	2	-				-	-	-	4				-	-	-	-
5					-	-	1					-	-	-					-	-	2					-	-	-
6						-	13						-	-						-	7						-	-
7							-							-							-							-

Figure 18. Initial Solution of Accepted Bookings; Based on Broihan et al. (2018).

In order to examine sensitivities, the maximum permissible CO_2-emission over the entire fleet was set at 1,000 g per time frame (Figure 19). This corresponds to a reduction of approximately 55% compared to the initial results. As assumed, a decrease in the use of diesel-powered vehicles can be observed, which reduces the used time frames of both stations from 175 to 49. The implementation of this CO_2-threshold lowers the objection function value to 3,032 €, which corresponds to a reduction of approximately 44% (3,799 €) compared to the initial solution. In comparison to the first-come first-serve principle, a 69% (1,242 €) improvement in the CO_2-limited case can be achieved by applying the revenue management approach presented.

CO_2 low	Station 1														Station 2													
	Diesel							Electric							Diesel							Electric						
Ending Time Frame / Starting Time Frame	2	3	4	5	6	7	8	2	3	4	5	6	7	8	2	3	4	5	6	7	8	2	3	4	5	6	7	8
1	-	-	-	-	-	-	-	11	2	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-
2		-	-	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-
3			9	-	-	-	-			-	-	-	11	-			9	8	-	-	-			-	-	-	10	-
4				-	-	-	-				-	-	2	-				-	-	-	-				-	-	-	-
5					-	-	-					-	-	-					-	-	-					-	-	-
6						5	1						-	-						4	2						-	-
7							-							-							-							-

Figure 19. Accepted Bookings with Maximum CO_2-Emission; Based on Broihan et al. (2018).

4.4. Contributions, Limitations, and Future Research

The developed mathematical model is a first approach for operative decision support in station-based carsharing business. The presented optimization model on demand-side related revenue management was adapted from the hotel business due to similarities between both industries. The approach allows for optimization of differently structured networks with regards to vehicles and stations; the examples only contain two stations for reasons of illustration. The article contributes to the field of revenue management, efficient carsharing operation, as well as ecological and economic sustainability.

Future research should address certain limitations of our approach. Regarding the optimization model itself, the approach could be modified in terms of the transformation from MINLP to a MILP as calculation times were reduced, even though the time observed for the small examples takes only a few minutes. Possible enhancements include the creation of shorter time frames together with a minute- and/or kilometer-based billing. In our approach, the demand is fixed and does not vary, if for instance, emission limits were introduced. Finally, it has to be mentioned that not every station-based carsharing organization operates with reservations. In such cases, revenue management and the developed model is not applicable.

5. Customer Acceptance of Ridepooling

5.1. Academic Classification

This section discusses factors of the customer acceptance to use ridepooling in two consecutive articles. The first publications has the title “An Empirical Study of Customers’ Behavioral Intention to Use Ridepooling Services – An Extension of the Technology Acceptance Model”. Six authors have contributed to this work: Marc-Oliver Sonneberg, Oliver Werth, Max Leyerer, Wiebke Wille, Marvin Jarlik, and Michael H. Breitner. This paper was submitted and accepted after one revision (three reviewers and one track chair) at the 14th International Conference on Wirtschaftsinformatik (WI) 2019 in Siegen (Sonneberg et al., 2019b and Appendix M). The theme of the WI 2019 was “Human Practice. Digital Ecologies. Our Future”. With an overall rate of 34% full conference papers accepted, our article was part of the track “Logistics Analytics” with an acceptance rate of 20% (Ludwig and Pipek, 2019). The WI is the main conference of the German language information systems community. In the JQ3, the proceedings of the peer-reviewed conference are rated “C”. In the WKWI rating, it is ranked “A”.

The topic of ridepooling acceptance was further analyzed within a second investigation whose results were submitted to the journal Transportation Research Part A. With the title “Behavioral Intention to Use Ridepooling Services – Empirical Insights and Recommendations”, the article was a collaboration of Oliver Werth, Marc-Oliver Sonneberg, Max Leyerer, and Michael H. Breitner (Werth et al., 2020 and Appendix T). The journal is rated “B” in JQ3 and dispose an IF of 3.693. The manuscript is still under review. *The following section 5 is largely based on Sonneberg et al. (2019) and Werth et al. (2020).*

5.2. Problem Description and Design of the Study

Ridepooling “has not apparently promoted transportation sustainability to date” (Merlin, 2019: 1). With the business model of ridepooling developed, success factors investigated, matching algorithms engineered, and theoretical impacts on traffic and emissions calculated, the question arises why the service is not accepted and used accordingly. Up to date, only Spurlock et al. (2019) investigated, among other NMS, the concept of ridepooling in terms of acceptance. In an American study, an adoption rate of 18% was found. Young low to middle incomers recognize predicted cost advantages and reduced environmental impacts of ridepooling. As the long-term success of a ridepooling service depends heavily on customer acceptance, the investigation of the following research question tackles this gap:

Which constructs influence customers' ridepooling services acceptance, and which implications and recommendations can be drawn from the data for ridepooling providers?

To answer this question, the hypotheses illustrated in Table 6 were adapted from the TAM to the context of ridepooling. The hypotheses H1 to H10 were examined in Sonneberg et al. (2019), whereas all hypotheses were contained within the subsequent study of Werth et al. (2020). To allow for comparability, the corresponding items were identical in both studies.

Table 6. Overview of Hypotheses; Based on Sonneberg et al. (2019b) and Werth et al. (2020).

H1	ATU has a significant positive influence on the BI to use ridepooling services.
H2	PU has a significant positive influence on ATU ridepooling services.
H3	PU has a significant positive influence on the BI to use ridepooling services.
H4	PEOU has a significant positive influence on ATU ridepooling services.
H5	PEOU has a significant positive influence on the PU of ridepooling services.
H6	PC has a significant positive influence on the PU of ridepooling services.
H7	PC has a significant positive influence on ATU ridepooling services.
H8	PC has a significant positive influence on the BI to use ridepooling services.
H9	PS has a significant positive influence on the ATU ridepooling services.
H10	SN has a significant positive influence on the BI to use ridepooling services
H11	EA has a significant positive influence on the BI to use ridepooling services.
H12	PV has a significant positive influence on the BI to use ridepooling services.

The hypotheses were tested via data collection from online surveys. Distribution of the surveys was established via e-mail through our transportation research network and on social media. After collecting demographic data, a brief introduction to the topic of ridepooling was provided to the participants. Measuring on a seven-point Likert scale ranging from "strongly disagree" (1) through "neutral" (neither disagree nor agree) (4) to "strongly agree" (7), the participants should answer the questions to items and constructs truthfully. Sonneberg et al. (2019) achieved 115 full questionnaire responses in March 2018, while Werth et al. (2020) received 224 complete datasets in the period from May to June 2019.

PLS-SEM was performed with the help of the software package *SmartPLS*. A two-step approach was used for measurement validation and model testing, as recommended by

Hair et al. (2016). To do so, indicator reliability, composite reliability, and convergent and discriminant validity were checked. Based on this procedure, only few items were extracted from the calculation. To analyze the structural model, a bootstrapping procedure with 5,000 replications was performed (Henseler et al., 2015), calculating the path coefficients and the coefficients of determination (adjusted R^2).

5.3. Discussion of Results and Recommendations

In the following, the results of first study are initially described separately. When presenting the results of the second study, both outcomes are additionally compared and discussed by chronologically dealing with each hypothesis. Figure 20 illustrates the results of Sonneberg et al. (2020), while Figure 21 depicts these of Werth et al. (2020).

The study of Sonneberg et al. (2019) reveals a significant and positive moderate influence of ATU on BI to use ridepooling with the consequence that H1 can be confirmed. For H2, a significant strong positive influence of PU on ATU can be observed too. A significant relationship of PU on BI to use ridepooling (H3) cannot be confirmed even though a positive influence is evident. Regarding PEOU, H4 and H5 are not supported as influences are low and insignificant. As hypothesized in H6, PC has a strong significant influence on PU. H7 (PEOU on ATU) can be supported too with significant moderate effects. H8 is supported, as PC has a significant positive impact on BI ridepooling services. H9 investigates PS on ATU, which is rejected due to insignificant effects. H10 can be affirmed as SN has a significant positive influence effect on BI to use ridepooling.

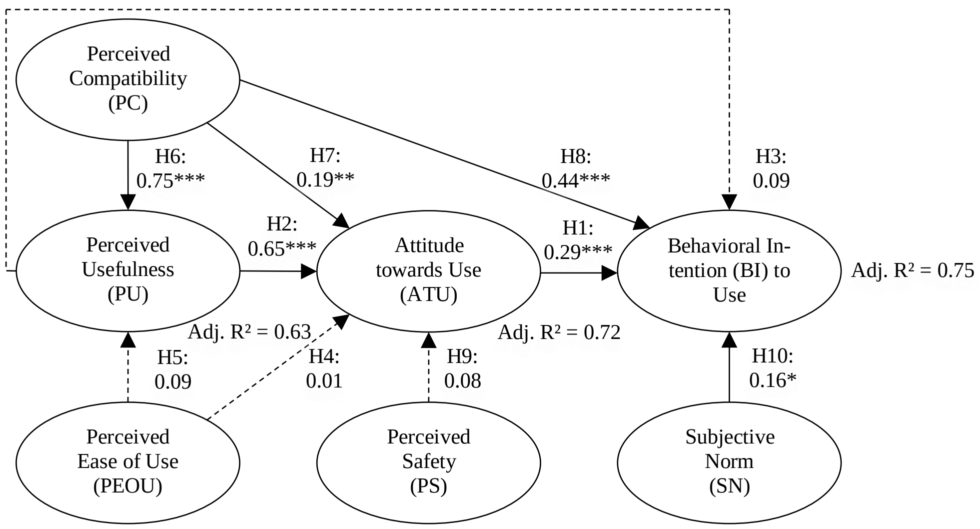


Figure 20. Results of the Path Analysis; Based on Sonneberg et al. (2019b).

*Notes:*p<0.1; **p<0.01; ***p<0.001; n=115; Dotted lines represent insignificant paths.*

Represented in Figure 20, H1, H2, H6, H7, H8, and H10 are supported while rejected hypotheses are represented by dotted lines. Regarding the endogenous variables, the adjusted coefficient of determination (R^2) was 0.63 for PU, 0.72 for ATU, and 0.75 for BI to use explaining the explanatory power.

The second study (Werth et al., 2020) considered also environmental awareness and price value of ridepooling. Besides, identical constructs and items are used. As first large variation, H1 cannot be confirmed due to non-significance. The results indicate that customers' ATU for ridepooling is not a requirement for BI to use this NMS. This is surprising because this relationship is a core relationship of TAM. Yang and Yoo (2004) note that such an outcome is possible. When separating cognitive and affective ATU, cognitive attitude has an influence on BI but affective attitude does not have any influence (Yang and Yoo, 2004). To conclude, the measurement of ATU on BI to use ridepooling needs further investigation. For the effect of PU on ATU (H2), similar results were observed as both studies reveal a strong significant influence in the case of ridepooling. Contradictory to our first study, PU has a significant influence on BI. Based on the confirmation of H2 and H3, ridepooling providers must address the PU of their services to gain high service levels. PEOU has significant positive influence on the PU and ATU of ridepooling (H4 and H5). This stands in contrast to the initial study. Regarding this construct, scientific discussions about the doubtfulness of the construct is available (e.g., Lee et al., 2003). Based on the results of Werth et al. (2020), ridepooling providers should offer an intuitive handling of the service by enabling easy booking and usage processes. If a customers perceives ridepooling as easy to use, they will find the service useful and will create an attitude towards it. Regarding H6 and H8, the results are line with Sonneberg et al. (2019). However, H7 is rejected due to an insignificance of PC on ATU, which is inconsistent with the initial study. Crucial for ridepooling providers is the focus on the usefulness of the transport service, which should be highlighted. Safety aspects (H9) are not relevant in both studies, as a ridepooling trip with other customers or unfamiliar drivers is not hindered the usage of such services. Quite relevant, and also in line with the first study, is the SN. The adoption of ridepooling depends on family members and friends and their experiences of such services. As a result, positive recommendations are important for the success of ridepooling services. Therefore, negative impressions of the service should be avoided especially in the beginning. In literature, this effect is explained by the so-called early adopters, who influence late adopters to use or avoid such services (Frattini et al., 2014). Regarding H11, no significant influence can be found. This means, environmentally friendly individuals would not use ridepooling services more or less than other individuals. Such an effect is not evident at the first time, but when analyzing today's low utilization rates of ridepooling services with additional kilometers travelled and unfeasible trip matching, this customer setting could be present. As recommendation for ridepooling providers, our result suggest not to focus on the environmental aspects and relating theoretical implications. There is also no obtained significance in terms of PV on BI to use ridepooling services (H12). As significant in several transportation contexts (e.g., Chen et al., 2017), this outcome is surprising at a first glance. When analyzing the reasons for using ridepooling services, this effect become comprehensible. Ridepooling is mostly used for leisure trips on short distances. Commuter or frequently conducted trips are not in focus of customers as other transportation modes are available. To conclude, this explains, why prices are not significant for the usage of ridepooling.

When comparing the endogenous variables, the second study reveals less explanatory power with an adjusted R^2 of 0.63 for BI to use ridepooling services. Consequently, lower adjusted R^2 values result for PU (0.43) and ATU (0.55). In this study, only 55.4% had knowledge of ridepooling services (67.0% in Sonneberg et al., 2019) whereas in both studies around 30% of participants already used this service. Based on the findings, other unknown constructs that could be important for the acceptance of ridepooling services are absent in both models.

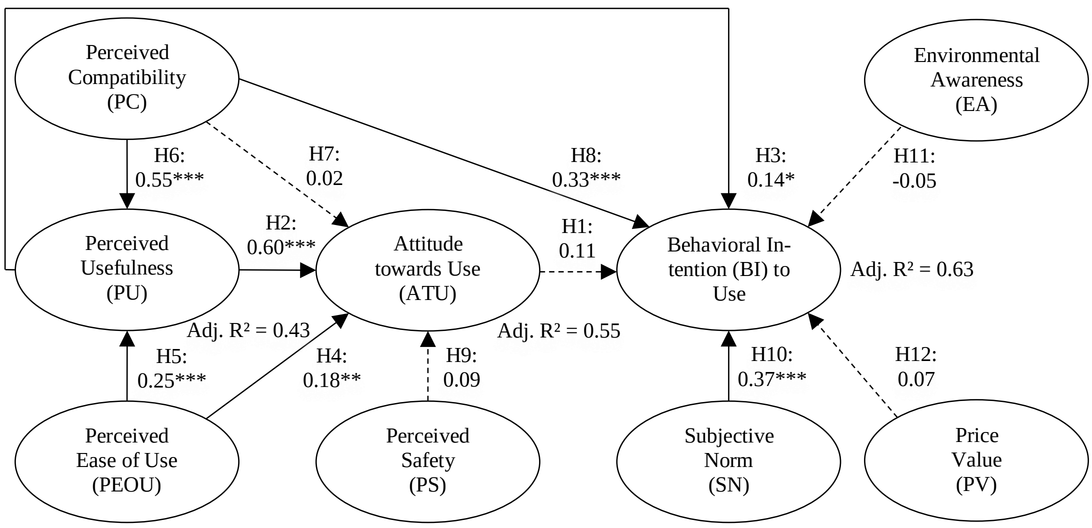


Figure 21. Results of the Path Analysis; Based on Werth et al. (2020).

*Notes:*p<0.1; **p<0.01; ***p<0.001; n=224; Dotted lines represent insignificant paths.*

5.4. Contributions, Limitations, and Future Research

Within two conducted studies, the customer acceptance of ridepooling services was investigated and the obtained results were compared. By testing the adapted TAM, possible relevant constructs regarding the BI to use ridepooling services were evaluated. In terms of theoretical contribution, the existing acceptance literature on ridepooling was expanded and the constructs of EA and PV to TAM-contexts were added. The repeated and extended study permits the observation and analysis of the acceptance, which is especially crucial for suitable marketing activities (Peres et al., 2010). In doing so, practical implications for ridepooling services were drawn. However, both studies are subject to various limitations.

The TAM itself is criticized for its too simple constructs. Academics draw a lot research to several aspects, as, for instance, the measurement of PU in terms of an innovation (Benbasat and Barki, 2007; Straub and Burton-Jones, 2007). Despite existing criticism, the TAM is often used to measure acceptance of technology-driven innovations. This is also true for transportation contexts regarding ridesharing or ridehailing (e.g., Giang et al., 2017; Ruangkanjanases and Techapoolphol, 2018; Wang et al., 2020). Consequently, it is proposed to apply more recent theoretical frameworks as for instance the UTAUT2 (Venkatesh et al., 2012) or the combination of the TAM with expectation disconfirmation theory (e.g., Prekumar and Bhattacherjee, 2008). Due to the use of other theories, a more profound understanding of ridepooling services could be achieved. As another limitation, our dataset of respondents contains mostly German students. To overcome this limitation, further research on a more diverse dataset with respondents from different age groups, professions, and ridepooling experiences is required. Such an examination could also reveal the influence of age-specifics and cultural factors on the acceptance of ridepooling services. In general, future research should investigate the analysis of the acceptance and success of ridepooling by continuous observation. As a consequence, this would also bring clarity regarding the partially different results of the two presented studies. Further, this would permit a greater understanding for both service providers and scientists in the comparatively young research topic of ridepooling.

PART B: URBAN LOGISTICS

<table>
<tr><td colspan="10">Physical Transport</td></tr>
<tr><td colspan="5">Passenger Transport</td><td colspan="5">Freight Transport</td></tr>
<tr><td colspan="2" rowspan="2">Private Passenger Transport</td><td colspan="6">Commercial Transport</td><td colspan="2" rowspan="2">Private Freight Transport</td></tr>
<tr><td colspan="2">Commercial Passenger Transport</td><td colspan="2">Commercial Service Transport</td><td colspan="2">Commercial Freight Transport</td></tr>
<tr><td colspan="4">Urban Mobility</td><td colspan="6">Urban Logistics</td></tr>
<tr><td colspan="10">Urban Transport</td></tr>
</table>

Figure 22. Classification of Transport Modes: Urban Logistics; Adapted from Arndt (2010).

"The need to rethink and rationalize urban logistics is being pushed into the front scene by the boom in the number of shipments (exacerbated by the growth of online shopping). It is also influenced by the general public's growing focus on the negative environmental and societal impact of fuel-driven deliveries in already saturated urban centers."

Van Audenhove et al. (2015:10)

"Urban Logistics are essential for cities to function successfully and make up a significant share of urban traffic. However, logistics are often neglected in urban planning."

European Commission (2020:1)

A Primer to Urban Logistics

Urban logistics is defined as "the movement of goods, equipment and waste into, out, from, within or through an urban area" (European Commission, 2013:2). Oftentimes also used as a synonym, the term city logistics is specified as the "process for totally optimising the logistics and transport activities by private companies with support of advanced information systems in urban areas considering the traffic environment, the traffic congestion, the traffic safety and the energy savings within the framework of a market economy" (Taniguchi et al., 2001:2).

Urbanization in combination with rising individual demand for goods as well as services and the continuous growth of e-commerce leads to increased transport activities in cities. As a result, increased traffic and pollution influence the city dwellers' health and quality of life. In contrast to sustainable urban mobility modes for passengers, a topic already addressed in practice and research, promising solutions for the sustainable transport of goods and services to customers is lacking. Behrends et al. (2008) define urban freight transport as sustainable, if the accessibility to all freight transport purposes is given, if air pollution, emissions, waste, and noise is reduced, and if resource and energy efficiency is improved.

Regarding the (global) supply chain, the last mile delivery (LMD) of goods and services is depicted as the most cost-intensive part of the transport chain (Gevaers et al., 2009). Most urban logistics activities are actually performed by conventional powered vans and trucks. Today, transporters (e.g., courier, express, and parcel (CEP) service providers) but also politicians and city authorities are engaged in developing sustainable and eco-friendly logistics concepts and strategies. Van Audenhove et al. (2015) described four different areas (regulation, infrastructure, incentives, and technology), which have to be combined to reduce the traffic induced by urban logistics. The sole substitution of conventionally powered vehicles with alternative eco-friendly ones is not an appropriate solution, especially, as corresponding vans' and trucks' availabilities are quite limited to-date (Van Audenhove et al., 2015). The implementation of additional urban transshipment points within the supply chain enables shorter LMD activities. This ensures the deployment and efficient use of alternative transport vehicles, e.g., cargo cycles or delivery robots. These additional transshipment points are called micro-hubs, micro-depots, urban consolidation centers, urban distribution centers, or satellites. Besides traditional delivery, these infrastructures can be equipped with appropriate technology that allows customer self-collection, if desired. The installation of transshipment points (further referred to as micro-hubs) in combination with alternative delivery modes are subject of investigation of several projects (e.g., *pro-e-bike*, *cyclelogistics*, *Civitas*, *FREVUE*, and others). While testing these innovative concepts, requirements for manufacturers producing eco-friendly transport vehicles can be derived. Best practices are shared to allow for further investigations on other cities or urban areas. Most of these projects and underlying concepts are specifically tailored to CEP service providers. Successfully tested and proven resource-saving concepts are transferred to real operation after completion of the project with the overarching goal of a more sustainable way of urban life.

Researchers have contributed to different aspects of LMD and sustainable urban freight transport. Investigations on e-commerce related customer habits and potential changes are, for instance, subject to the studies of Barone et al. (2014) and Manerba et al. (2018). Modifications in the existing infrastructure of the road network (e.g., traffic restrictions, toll systems, (un-)loading zones) or analyses regarding involved stakeholders of urban logistics concepts are discussed in, e.g., Figliozzi and Tipagornwong (2017), McLoed et al. (2019), and Taniguchi (2014). With a focus on costs, impacts, and best practices, Castrellón-Torres et al. (2018), Fossheim and Anderson (2017), and He and Haasis (2019) evaluate new logistics concepts, as, for instance, white-label or night logistics. Digiesi et al. (2017), Ranieri et al. (2018), and Tob-Ogu et al. (2018) investigate the possibilities to reduce different kinds of externalities. Most promising are proximate micro-hubs, collaborative delivery, and (autonomous) electric vehicles, in combination with information and communication technologies (ICT). Concepts incorporating these elements into the LMD are introduced in this part of the dissertation for optimization and acceptance.

Optimization of Urban Logistics Concepts

Regarding the optimization of LMD, strategic, tactical, and operational decisions have to be distinguished. At a strategic level, the number, locations, and sizes of facilities as well as technologies of employment are crucial (Lahyani et al., 2015). Physical and functional components, more precisely the size and composition of the transportation or delivery fleet, are part of the tactical decision level (Bielli et al., 2011). The daily delivery process in terms of routing and associated decisions are examined at the operational level

(Schmidt and Wilhelm, 2000). In urban logistics contexts, several approaches focus on two levels, for instance, by combining location and routing decisions at the same time (Prodhon and Prins, 2014).

In the following sections 6 to 9, various promising concepts are introduced, analyzed, and optimized with respect to network design and/or routing addressing the mentioned decision levels. Section 6 presents an approach for optimization of individual customizable routing problems for commercial transport operators. A concept consisting of micro-hubs and cargo cycles for CEP service providers is investigated in terms of location and routing optimization in section 7. Routing of autonomous delivery robots is optimized in section 8. Section 9 describes an optimization approach for e-grocery deliveries by means of cargo cycles and refrigerated parcel lockers in terms of consecutive locations, fleet, and routing decisions.

For all of these approaches, the methodology of DSR was applied to secure efficient artifact generation. Figure 23 illustrates the cycles with regard to the topic of urban logistics.

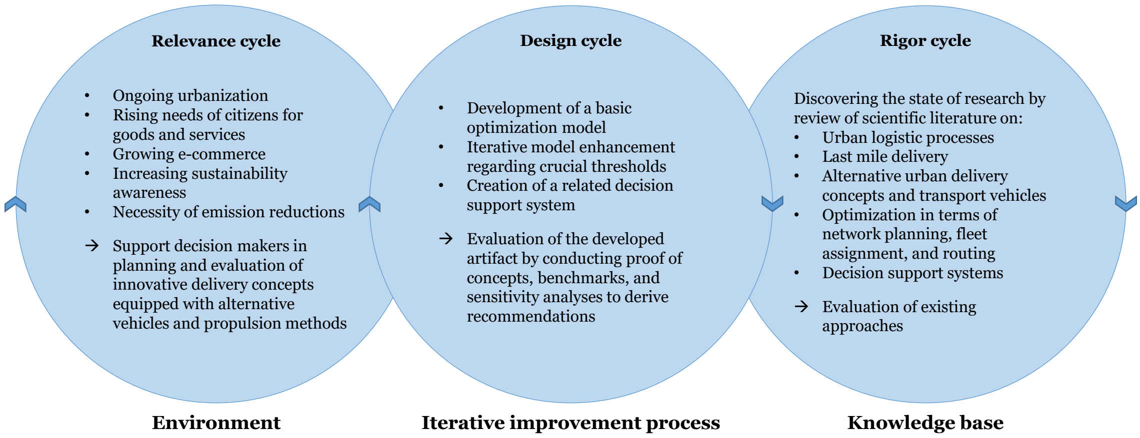


Figure 23. DSR-Cycles Applied to Urban Logistics; Adapted from Sonneberg et al. (2019a).

Acceptance of Urban Logistics Concepts

As scientific investigations regarding the customer acceptance of urban logistics processes are rare, several delivery concepts were examined by applying the UTAUT framework as theoretical foundation. UTAUT is described as empirically validated synthesis of eight different acceptance models with a focus on technology usage (Venkatesh et al., 2003). It was developed to predict the probability of success for the introduction of a new technology into corporate contexts. UTAUT encompasses four elementary constructs serving as indicators of the user's intention to behave, namely performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC) (Venkatesh et al., 2003). These exogenous constructs serve as indicators to measure the influence on the BI and use behavior (UB) depicting the endogenous latent variables. UTAUT was revised (UTAUT2) to allow for acceptance measurement in customer settings. Therefore, the constructs of PV, hedonic motivation (HM), and habit (HT) was added. Further, the moderator variables age, gender, and experience are required to investigate the effect on the constructs and to determine the magnitude of variables (Venkatesh et al., 2012).

To fit to the context of urban logistics and to account for actual discussions on sustainability issues, the construct of sustainability expectancy (SE) was included. SE reflects the corresponding awareness level of the customers to the examined concepts in, e.g., energy-saving features (Kwon and Song, 2012). Figure 24 provides an overview of constructs with regard to the resulting UTAUT2 framework that forms the foundation for the acceptance study of section 10.

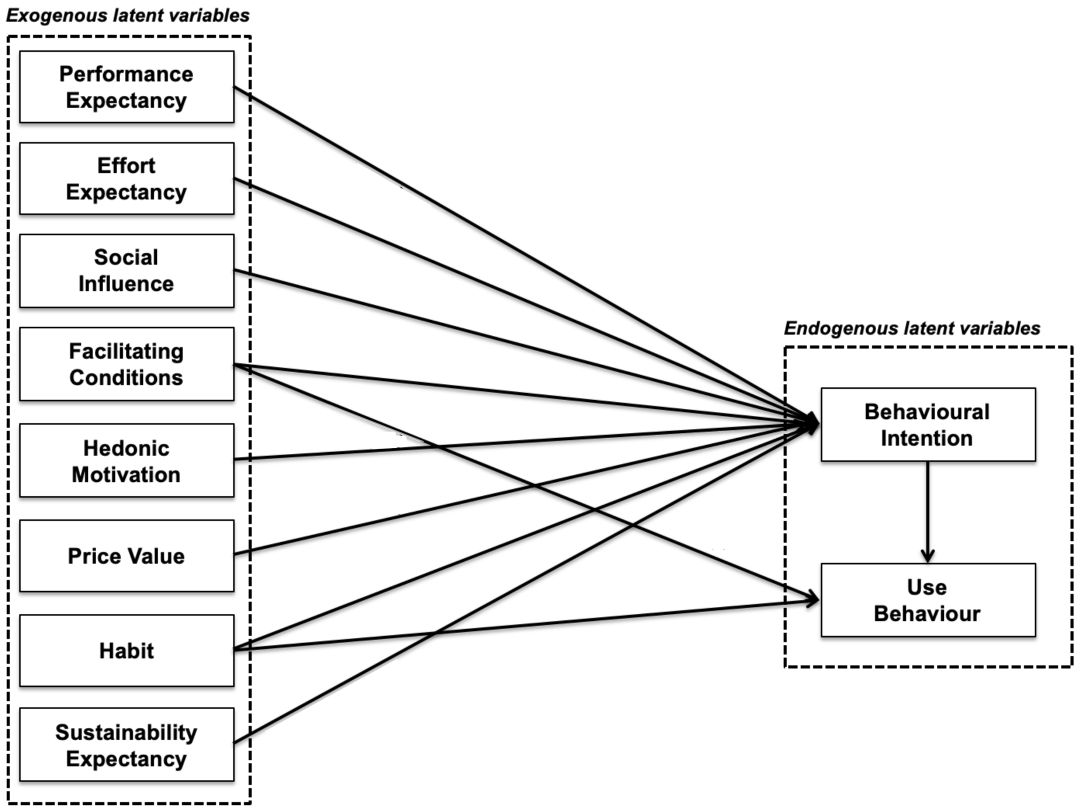


Figure 24. Adapted UTAUT2 Framework; Based on Sonneberg et al. (2019c).

6. Optimization of Individual Commercial Road Transport

6.1. Academic Classification

In this section, the research article "Individually Optimized Commercial Road Transport: A Decision Support System for Customizable Routing Problems" is discussed (Leyerer et al., 2019a and Appendix P). The article is a collaboration of Max Leyerer, Marc-Oliver Sonneberg, Maximilian Heumann, Tim Kammann, and Michael H. Breitner. The article was submitted to the special issue on "Sustainable Urban Logistics" of the journal Sustainability. After a single-blind peer-review with two revision rounds and four reviewers, the article was accepted for final publication. Sustainability is an international, cross-disciplinary, and open access journal investigating environmental, cultural, economic, and social sustainability (Sustainability, 2020). The journal is rated "C" within the JQ3 and dispose of an IF of 2.592. The article was funded by the *Open Access fund of the Leibniz Universität Hannover*. *The following section 6 is largely based on Leyerer et al. (2019a).*

6.2. Problem Description and Optimization Approach

For companies classified to the commercial freight and service transport sector, the distribution system and the delivery itself depict an important cost factor. With optimized routes, significant savings up to 30% are possible as several studies demonstrate (e.g., Hasle and Kloster, 2007). These savings do not only have advantages for the company itself but also for the environment as a whole, as transport kilometers and thus emissions are saved. The assignment of customers to vehicles and routes is part of Vehicle Routing Problems (VRP) (Toth and Vigo, 2001). VRP support operational decisions concerning various transport processes of goods and services (Lahyani et al., 2015). Small instances can certainly be solved manually, but in business contexts, this is usually not possible due to various constraints as for instance time windows (Rademeyer and Lubinsky, 2017). The field of VRP research is intensively researched since more than 50 years in various business contexts (Laporte, 2009). In recent years, existing research has been criticized as "being too focused on idealized models with non-realistic assumptions for practical applications" (Hartl et al., 2006:103). Routing software is mostly used by companies whose core competence and economic business operations are strictly focused on the transport sector, e.g., CEP service providers, or long-haul transporters (Drexl, 2012). Focusing on urban commercial transport, small- and medium-sized companies operating an own fleet behave mostly according to their accumulated experience and best practices not making use of routing software. Examples for such companies are newspaper delivery, solid waste collection, or craftsmen-, parcel-, pharmacy-, e-grocery-, and care-services. The application of routing optimization would lead to substantial savings with respect to travel distance, travel time, travel costs, vehicle emissions, and the resulting overall traffic volume. To allow for individual routing optimization for those companies without optimization knowledge, the following research question guides our process:

How can a customizable VRP be implemented into a DSS enabling route optimization for urban logistics applications of several industries?

Following the overall purpose of creating a DSS for a variety of real-world routing problems, relevant aspects and restrictions for practical goods and services delivery applications have to be extracted. These aspects are typically called attributes. Following the literature search guidelines of Kitchenham et al. (2009), investigation regarding the field of real-world VRP, classification of attributes and optimization objectives, and grouping of these in accordance with Eksioglu et al. (2009) and Lahyani et al. (2015) was carried out and visualized in Figure 25.

I. Information Characteristics		**II. Problem Physical Characteristics**		**III. Routes Characteristics**		**IV. Objectives Characteristics**
input data +input evolution └static └dynamic +input quality └deterministic └stochastic *travel mode* └unimodal └multimodal *vehicles* └unlimited number └bounded number *customer requests* └pickup or delivery └pickup and delivery	*depots* └single └multiple *periods* └single └multiple *product types* └single └multiple	*vehicles* +type └homogenous └heterogeneous +capacity └unrestricted └capacitated +range └unlimited └limited +structure └no compartments └compartmentalized +loading policy └no policy └specific ordering *drivers* └no regulations └regulations	*customers* └unrestricted └inventory considerations *depots* └unconstrained └capacitated *times* └unconstrained └time dimension +time window structure └single time window └multiple time windows +time window components └customers/requests └depots └vehicles/drivers └roads	*node covering* └complete └optional visits *visit frequency* └single visit └multiple visits / load splitting *depot connectivity* └closed routes └open routes *vehicle use* └single trip └multiple trips	*incompatibilities* └all compatible └incompatibilities *node coupling* └no precedence └precedence constraints *routes balancing* └no balancing └balanced routes	*structure* └single objective └multiple objectives └weighted sum └hierarchical ordering *hardness of constraints* └hard constraints └soft constraints *components* └distance └times └vehicle/driver └customer/request └depot └load └other

Figure 25. Classification of (Implemented) VRP-Attributes; Based on Leyerer et al. (2019a).

Existing attributes are assigned to the groups' information characteristics (including input data und strategical components), problem physical characteristics (including fleet and customers related issues), route characteristics (including delivery specifics), and objective characteristics (including possible optimization goals). Additionally, Figure 25 highlights the high flexibility of attributes and wide range of applications. Black font attributes (26 out of 32) are selectable for routing optimization within the developed DSS, while red marked are not implemented yet.

Regarding the computation time, the DSS must provide quick routing recommendations for the decision maker. Thereby, it should be noted that VRP are proven to be non-deterministic polynomial-time (NP)-hard, which is why exact solution methods are pushed to their limits even in smaller instances (Lenstra and Kan, 1981). Due to this condition, researchers commonly use approximate heuristic solution approaches for solving VRP and obtain good results on large-size problems (Cordreau et al., 2002; Lahyani et al., 2015). To solve the individual user-specific VRP based on the selected attributes, these were optimized with the software *LocalSolver*. The software makes use of a local search heuristic, which explores the solution space by iteratively moving from the current solution to another promising solution in its neighborhood. The *Local Search Programming* (LSP) language was used to develop corresponding constraints for the attributes and objectives of Figure 25 in one model. LSP dispose characteristics of a typical scripting language but is dedicated to modeling and solving a problem (Gardi et al., 2014). To allow for short computation times, only the selected attributes are passed to *LocalSolver*, which is achieved with an extensive set of conditional statements in the LSP model file activating or deactivating attributes and attribute combinations. By means of examples for an attribute (vehicle capacity) and an example for an objective (balanced route duration), the corresponding LSP-code is demonstrated and compared with the typical mathematical formulation with the LSP-code.

Equation (1) defines the vehicle load of the first sequence as the sum of the demand quantity at the first customer location n and an initial load of the vehicle k $\left(q_k^{init}\right)$. In case of a pickup node, the demand $q_{n(k,1)}$ is positive and negative in case of a delivery node. For subsequent node p in the tour, the actual load is the recursively defined in function (2). The capacity of $Load_{k,p}$ varies for each vehicle according to the number of associated visits in a tour c_k. Constraint (3) ensures that the positive current load does not exceed the vehicle specific capacity $\bar{q}_k^{vehicle}$. The specific vehicle capacity $\bar{q}_k^{vehicle}$ is set by constraint (3) limiting the actual capacity $Load_{k,p}$.

$$Load_{k,1} = q_k^{init} + q_{n(k,1)} \qquad \forall\, k \tag{1}$$

$$Load_{k,p} = Load_{k,p-1} + q_{n(k,p)} \qquad \forall\, k, p \in 2, \dots, c_k \tag{2}$$

$$0 \leq Load_{k,p} \leq \bar{q}_k^{vehicle} \qquad \forall\, k, p \in 1, \dots, c_k \tag{3}$$

If translating the vehicle capacity constraints into LSP-code, it has to be differentiated between single and multiple trips. For a single trip (line 2 and 3) of Figure 26, the variable load $currentLoad[k][i]$ for each vehicle k and stop i is bound to the maximum capacity $truckCapacity[k]$ of the allocated truck and ensures a value greater than zero. As visible, the vehicle capacity is modeled as hard constraint that has to be met in each iteration.

```
1  if(currentLoadConstraint) {
2    if (singleTrip)constraint and(0..c-1, i => 0 <= currentLoad[k][i] && currentLoad[k][i]
3    <= truckCapacity[k]);
4    if (multipleTrips)constraint and(0..c-1, i => currentLoad[k][i] <= truckCapacity[k]);}
```

Figure 26. LSP-Code for Vehicle Capacity; Based on Leyerer et al. (2019a).

Regarding the even distribution of the route duration for all drivers, an imbalance function is to be minimized. Equation (4) defines the imbalance as the maximum value out of zero and the difference between the minimum and maximum tour duration $Dur^{difference}$ minus the average duration weighted by the tolerance factor $\beta * \left(\sum_k \frac{Dur_k^{tour}}{Z_k}\right)$.

$$min\left(imbalance = max\left\{0, Dur^{difference} - \beta * \left(\sum_k \frac{Dur_k^{tour}}{Z_k}\right)\right\}\right) \quad (4)$$

Contrary to the LSP-Code for the vehicle capacity, the even distribution concerning the route duration for all drivers is modeled as soft constraint in Figure 27.

```
5  if (balanceRouteDurations) {
6    routeMax <- max[k in 0..nbTrucks-1](routeDurations[k]);
7    routeMin <- routeMax;
8    for [k in 0..nbTrucks-1] {
9      routeMin <- ((routeDurations[k] > 0 && routeDurations[k] < routeMin)
10     ? routeDurations[k] : routeMin);
11   }
12   averageDuration <- totalDuration / nbTrucksUsed;
13   imbalance <- max(0, (routeMax - routeMin) - beta*averageDuration);
14 }
15 function readObjectives() {
16   if (hierarchicalObjectives) {
17     local P = hierarchical.split("_");
18     for [obj in 0..P.count()-1] {
19 […]
20       else if (toInt(P[obj]) == 18) {
21         minimize imbalance;}
22     }
23   }
24 }
```

Figure 27. LSP-Code for Balances Route Duration; Based on Leyerer et al. (2019a).

Before the imbalance minimization can take place (line 21), the relations of the imbalance function have to be defined (lines 5 to 14). Line 6 delineates the maximum tour length for each vehicle k. The shortest and longest tours are expressed in lines 7 to 11 associated to $routemin$. Line 13 then defines the imbalance including a weighting factor beta for a variable tolerance limit of the deviations in route duration. In this example, the code is shown for the case of the user choosing a hierarchical weighting of attributes (line 15 to 18). Thereby, the imbalance minimization is included in the objective function according to the selected target hierarchy.

6.3. Decision Support System

The DSS comprises five main components (model configuration, input data, optimization settings, solutions, and visualization), which are adjustable via the corresponding GUI (see Figure 28). The contained attributes of Figure 25 are customizable based on the desired routing optimization. While input data refers to customers, depots, vehicles, and their associations, user-sided configurations of the optimization process can be adjusted within the optimization settings. After final editing of the three components, all inputs are saved in a database (DB). By starting the optimization, an individual VRP based on the settings is created and transmitted to the software *LocalSolver*. The optimization starts automatically, corresponding results are saved within the DB. The user can display the solutions and visualize them via GUI in an embedded map. Through the usage of a DB, the user can calculate several projects with different settings and compare the results. Several *Google* application programming interfaces (API) work in the background calculating, for instance, distances and travel times between the contained locations.

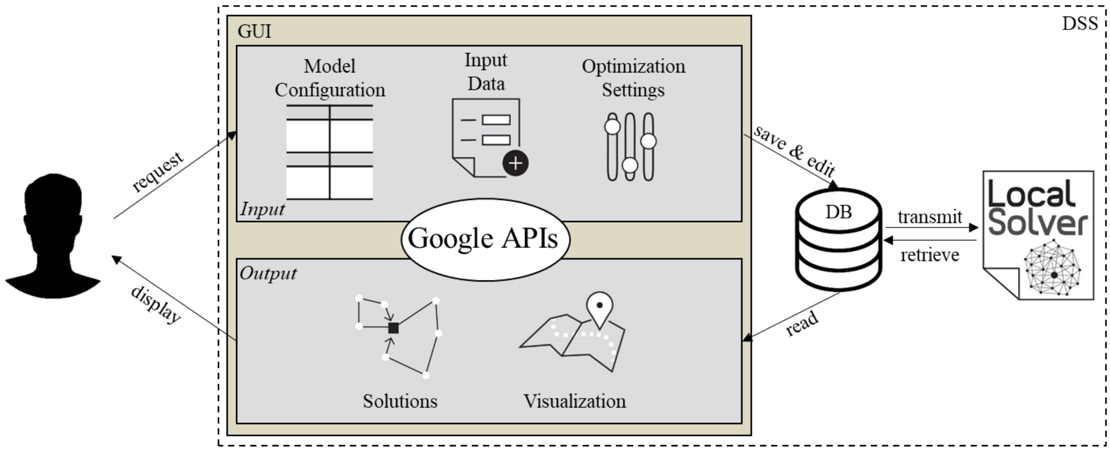


Figure 28. User Interaction and System Architecture of the DSS; Based on Leyerer et al. (2019a).

The following Figure 29 presents the GUI of the DSS during model configuration in terms of route characteristics. The web-application is adequately designed for end-users without programming skills or knowledge of optimization methods to optimize their business cases. A user-friendly interface together with information buttons and corresponding hover effects facilitate the usage of the application.

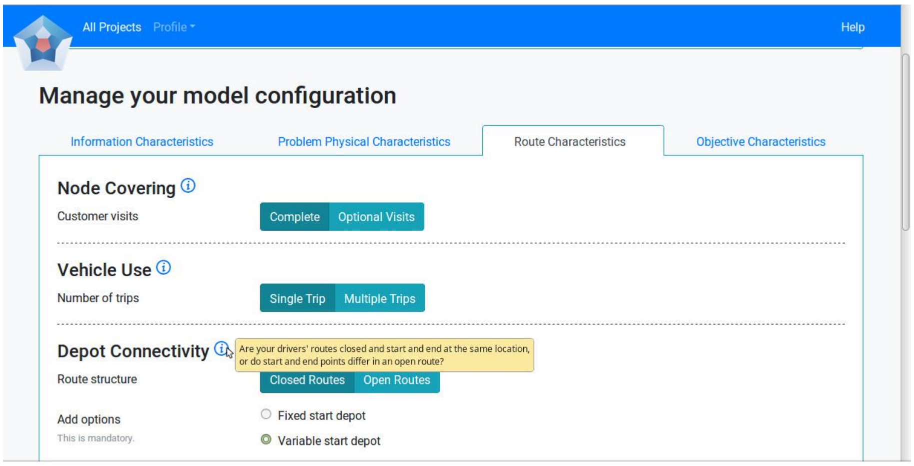


Figure 29. Screenshot of GUI during Model Configuration; Based on Leyerer et al. (2019a).

6.4. Application Example and Discussion of Results

The tool's performance was evaluated by a proof-of-concept as well as an adjacent real-word application example. The tool's solution performance on different routing problem variants with corresponding standard instances was compared to best performing solution methods on the respective instances. In the following, one exemplary routing variant comparison is presented. Calculations are conducted on a standard computer with an Intel Core i7 QuadCore CPU (2.2 GHz) and 8 GB memory. To receive quick decisions, which is required for real-world problems, calculations are aborted after 120 seconds.

Table 7 illustrates the comparison for the multi-depot VRP to three best performing algorithms, while standard instances of Cordeau et al. (1997) are applied (Cordeau and Maischberger, 2012). The three algorithms are *ALNS* (Pisinger and Ropke, 2007), *CGL* (Cordeau et al., 1997), and *ITS/1* (Cordeau and Maischberger, 2012) and are stated at the table head, whereby DSS depicts the results of the presented approach. The first column describes the problem instance and size of the multi-depot VRP. The column gap indicates the relative percentage gap of the heuristic solution to the best-known solution. The gaps reported by Cordeau et al. (1997) are based on best-known values. The column CT states the computation time in seconds. To clarify the dashes, *ITS/1* only report best results after 100,000 iterations, while an average computation time of 110 seconds is stated.

Table 7. Computational Results for the Multi-Depot VRP; Based on Leyerer et al. (2019a).

|N|: number of customer nodes; |M|: number of depot nodes; |K|: number of vehicles/tours

|N| x |M| x |K|	*ALNS*		*CGL*		*ITS/1*		DSS	
	Gap	CT	Gap	CT	Gap	CT	Gap	CT
50 x 4 x 4	**0.0**	29	**0.0**	15	**0.0**	-	**0.0**	12
50 x 4 x 2	**0.0**	28	0.1	50	**0.0**	-	**0.0**	14
75 x 5 x 3	**0.0**	64	0.6	17	0.1	-	**0.0**	22
80 x 2 x 5	0.1	75	0.1	1	**0.0**	-	**0.0**	42
100 x 2 x 5	0.3	120	0.4	79	0.2	-	3.4	31
100 x 2 x 8	0.5	88	0.6	336	0.5	-	1.5	32
100 x 3 x 6	0.7	93	0.2	293	0.4	-	3.4	48
100 x 4 x 4	0.8	88	1.1	427	0.7	-	1.9	40
160 x 4 x 5	**0.0**	179	0.4	539	**0.0**	-	7.1	28
240 x 6 x 5	0.3	315	**0.0**	10	0.3	-	5.5	54
249 x 2 x 14	0.8	333	2.5	1,175	2.2	-	7.0	102
249 x 3 x 12	0.5	361	1.6	419	1.7	-	5.4	88
249 x 4 x 8	0.5	363	2.3	984	1.7	-	5.2	89
249 x 5 x 6	0.8	357	1	1,040	1	-	3.5	110
360 x 9 x 5	0.5	582	1.1	1,786	0.7	-	0.9	78

The obtained objective function values are usually slightly worse than those of the three reference studies. To the best-known solution, the DSS using *LocalSolver* reaches results around an optimality gap of 5%. To sum up, decent and valuable solutions in short computation times are achievable with the DSS.

In addition to the comparison on problem-tailored VRP solution procedures, two real-world application cases are presented. Courier tours of a small-sized coffee supplier (three operating days) and a courier of a medium-sized CEP service provider (one operating day) are compared to the tool’s solution. The relevant attributes as introduced in Figure 25 of both cases are the following: given depot locations, given customer locations, a deterministic demand, only one product type, capacitated vehicles with a limited range, closed routes, and single customer visits. In the case of the coffee courier, customer-related time windows have to be met additionally. In both cases, the objective is set to minimize overall distances.

The coffee courier supplied up to 12 customers in urban surroundings per day, while the distance travelled ranged from 28.03 km to 42.07 km. Using the DSS, savings from 16.14% (4.61 km) to 42.75% (11.89 km) are achievable. On the sample day, the CEP courier travelled 44.27 km to deliver 119 parcels to 97 customers. With a computing time of 45 seconds, a driving distance of 27.52 km resulted with an efficiency gain of 37.83% (16.75 km). When comparing these results to an exact solution method (CPLEX), 24 hours of calculation are required to receive a solution of 28.94 km for the identical CEP courier instance. Thus, it can be confirmed that if real-world VRP is to be solved in a fast time, heuristic solution methods, as applied in the developed DSS, are needed. Besides the potential savings in terms of distance minimization, the described efficiency maximization further decreases resulting vehicle emissions and transport costs for the company. This results in advantages for the entire (urban) road infrastructure and its participants.

6.5. Contributions, Limitations, and Future Research

Guided along the three cycles of a DSR process, the DSS as final research artifact was created to provide relevant assistance for VRP optimization of diverse industries. Due to a literature review conducted, a lack of decision support for generic vehicle routing planning was identified as most approaches focus on problem-tailored solution approaches. For the implementation of a problem-specific business context, the attribute classification was developed to permit the execution for users without prior knowledge of VRP nor optimization methods. The DSS allows for generic route optimization leading to efficient vehicle utilization in urban logistics contexts. Decent solutions are obtainable through the use of *LocalSolver*. In comparison to problem-tailored solution approaches, the DSS is able to achieve similar results quickly. For small and medium-sized companies, problem-tailored approaches do not constitute a solution, as relevant and specialized attributes are not contained. This situation is tackled by a variety of implementable attributes to allow for individual optimization of goods and services. Compared to non-optimized routes, savings in terms of driving distances, costs, and emissions can be achieved by applying the developed DSS. The DSS is accessible via a web application, which is hosted on an efficient server, so companies do not need to have their own infrastructure. In doing so, the approach contributes to DSR applications for economic and environmental sustainability as well as the Green IS domain as the research addresses relevant issues regarding the efficient supply of people with goods and services in urban areas.

Regarding limitations, the DSS is not understood as a “one-size-fits-all” solution. There are definitely VRP specifications that cannot be modeled and consequently optimized. To be mentioned are practically relevant corporate strategies as for instance the avoidance of turning left and zigzagging (Holland et al., 2017) or local conditions regarding the parking situation at customers (Holguin-Veras et al., 2018). The DSS was developed to be a useful tool suitable for the optimization of several urban logistics delivery processes of small- and medium-sized companies. To allow for optimization in terms of vehicle utilization efficiency and its impacts, the right choice of attributes represents the most crucial part regarding the tool's performance. Although the tool's structure is kept as simple as possible with additional information to the attributes, potential user-sided error sources must be mentioned. First, adding too many attributes within the model configuration process complicates solution efficiency. Taking into account a driver's lunch break at a fixed time is theoretically possible to implement, but makes it more difficult to find a quick and decent solution. Second, the generated optimization model may lose its practical sense without real problem structuring constraints. Third, the DSS must provide support on different combinations of objectives, especially with respect to potential conflicts. Another possible source of error is the correct preparation of the raw data (contact, address, time window, etc.). Finally, a lot of effort was made to provide the best possible support to an unexperienced user of the DSS. To use the developed DSS, the company must own valid business licenses for the integrated software *LocalSolver* as well as the *Google APIs*. The latter could be replaced by open-source API, as for instance *OpenStreetMap*. When using the *Google API*, another limitation occurs, as they are used to retrieve the estimated travel times as well as distances between the locations of the system based on the actual traffic situation of the road network. Further research could amend travel time variability by implementation of time periods and related travel times to estimate road conditions more accurately. Yet, there are several other external events that may affect the routing during the day. For those reasons, the DSS allows for fast re-evaluation by use of a DB. To find out whether users without optimization and programming knowledge can use the tool efficiently, field tests regarding different commercial transporters as for instance newspaper delivery, solid waste collection, or craftsmen-, parcel-, pharmacy-, e-grocery-, and care-services are required. This is also advised for the methodology of DSR, as a deep empirical evaluation depicts a major part of the relevance cycle. As part of future research, mentioned limitations and contributions can be verified regarding the real-world utility of the DSS, which would increase the practicality, rigor, and generalizability of our approach.

7. Parcel Delivery Optimization with Micro-Hubs and Cargo Bicycles

7.1. Academic Classification

This section deals with the article "Decision Support for Sustainable and Resilience-Oriented Urban Parcel Delivery" (Leyerer et al. 2019b and Appendix R). Max Leyerer, Marc-Oliver Sonneberg, Maximilian Heumann, and Michael H. Breitner contributed to the article, which was published in the special issue on "Environmental Decisions" in EURO Journal on Decision Processes. In a single-blind peer-review process consisting of three revision rounds (three reviewers), the article was accepted for final publication. With the Association of European Operational Research Societies (EURO) as editor, the journal welcomes approaches on theoretical, methodological, behavioral, and organizational research topics to support the decision processes by applying OR methods (EURO, 2020). The EURO Journal on Decision Processes is strictly focused on special issues investigating actual topics twice a year. Due to this process, the journal has published only 108 articles since 2013. Within JQ3, the journal is listed but not equipped with a rate as too few academics (25 required) have participated within the rating process. Following the criteria of JQ3, the journal possesses scientific quality based on 17 academics and their corresponding rating (A+: 5.9%; A: 35.3%; B: 17.6%; C: 29.4%; D: 11.8%). *The following section 7 is largely based on Leyerer et al. (2019b).*

7.2. Problem Description and Optimization Approach

This approach focuses on urban commercial freight transport, more specifically on a concept for CEP service providers. It accounts for the rising number of parcels to be delivered and allows for a more sustainable way in contrast to the traditional delivery using vans or light-duty trucks. Within the LMD of CEP service providers, urban micro-depots are added to the supply chain. With these additional hubs, parcels are stored temporarily near end customers and distances covered by delivery vehicles are reduced. In doing so, alternative transport vehicles can be applied. The approach enables simultaneous optimization of urban micro-depot locations as well as the corresponding vehicle fleet. The described logistics concept is currently tested in real-world conditions, for example, by *UPS* in the cities of Frankfurt and Hamburg (UPS Pressroom, 2017). With the approach, CEP service providers are supported in planning and implementation of the investigated concept for large-scale applications in real operation.

The on-hand problem is characterized as Location Routing Problem (LRP) and combines the tactical location decision together with fleet planning and operational routing aspects. Such joint decision is a wide field of research (Prodhon and Prins, 2014). Scientific research on LRP investigates different solution methods, influences on externalities, impacts of homogeneous/heterogeneous fleets, cost effects, and the comparison of a single depot in contrast to several ones (Koç et al., 2016; Moutaoukil et al., 2015, Tricoire and Parragh, 2017). Further, Simoni et al. (2018), Winkenbach et al. (2016), and Zhao et al. (2018) present optimization approaches for the joint optimization of depot location, fleet assignment, and routing by including alternative transport vehicles. Despite the large number of relevant studies, no solution of an integrated parcel delivery approach exists. The simultaneously optimization of hub locations, vehicle assignment, and operating vehicle and crew allocation while reducing transport-related externalities implemented in a DSS, is missing. Therefore, the following research question is investigated:

How can decision makers be assisted in designing an eco-friendly and resilient parcel delivery network while quantifying its economic and environmental impacts?

To answer this question, a MILP for urban parcel delivery network planning was developed minimizing the monthly operating costs. To allow for the provision of decision support without optimization knowledge, a user-friendly DSS was created. The following assumptions form the foundation of the mathematical model.

The demand for parcels per day, which has to be fulfilled completely, is assigned to customers within an operation area. Possible hub locations, consisting of space for standardized containers itself and vehicle parking, are distributed throughout the investigation area. Space costs vary per hub location and containers are prepared for the delivery before the operation begins. A heterogeneous vehicle fleet is assigned to each hub, while vehicles differ in terms of costs, propulsion method, emission, range, and loading capacity. Based on these specifications, each vehicle has its maximum number of deliverable parcels per tour. Charging infrastructures for electric vehicles are available at each hub location to enable overnight recharging. Vehicles' leasing, maintenance, spare parts, and insurance costs (fixed costs), fuel consumption (variable costs), caused emissions, noise, and congestion (external costs), and courier (personnel costs) incur. Further, a maximum average amount of local CO_2-emissions over the entire fleet has to be set.

Before the mathematical model is presented, sets, parameters, and decision variables used are introduced:

Sets:

$i = (1, \dots, I)$: $transport\ vehicle\ type$

$j = (1, \dots, J)$: $potential\ hub\ location$

$k = (1, \dots, K)$: $demand\ location$

Parameters:

a: $available\ space\ per\ hub\ location$ $[m^2]$

b_i: $parcel\ delivery\ rate\ of\ vehicle\ type\ i$ $[\#/h]$

c: $monthly\ costs\ of\ a\ container$ $[€/\#]$

d_k: $parcel\ demand\ at\ demand\ location\ k$ $[\#/day]$

e_i: $local\ CO_2 - emissions\ of\ vehicle\ type\ i$ $[gCO_2/km]$

E: $maximum\ permissible\ CO_2 - emissions\ of\ the\ vehicle\ fleet$ $[gCO_2/km]$

F_i: $maximum\ number\ of\ vehicle\ type\ i\ per\ hubduration\ of\ a\ time\ frame$ $[min]$

g_i: $required\ parking\ space\ of\ vehicle\ type\ i$ $[m^2]$

h_j: $monthly\ space\ costs\ at\ hub\ location\ j$ $[€/m^2]$

l_i: $loading\ factor\ of\ vehicle\ type\ i$

m_i: $transport\ capacity\ of\ vehicle\ type\ i$ $[m^3/day]$

$\bar{n}$: $average\ parcel\ volume$ $[m^3]$

o: $number\ of\ operating\ days$ $[\#/month]$

p_j: $vaailable\ parking\ space\ at\ location\ j$ $[m^2]$

Q: $minimum\ distance\ covered\ by\ a\ vehicle$ $[km]$

r_i: $range\ of\ vehicle\ type\ i$ $[km/day]$

s: $storage\ capacity\ of\ a\ container$ $[m^3]$

T: $maximum\ delivery\ hours$ $[h/day]$

$u_{j,k}$: $distance\ between\ hub\ location\ j\ and\ demand\ location\ k$ $[km]$

U: $maximum\ distance\ between\ hub\ location\ j\ and\ demand\ location\ k$ $[km]$

v_i^{ext}: $external\ costs\ of\ vehicle\ type\ i$ $[€/\#]$

v_i^{fix}: $monthly\ fixed\ costs\ of\ vehicle\ type\ i$ $[€/\#]$

v_i^{ope}: $operational\ costs\ of\ vehicle\ type\ i$ $[€/km]$

w: $courier\ wage\ per\ hour$ $[€/h]$

Decision Variables:

$f_{i,j}$: $number\ of\ vehicles\ of\ type\ i\ at\ hub\ j$ $[\#]$

q_i: $distance\ covered\ by\ vehicle\ type\ i$ $[km/day]$

t: $total\ delivery\ time$ $[h/day]$

$y_{i,j,k}$: $1, if\ demand\ location\ k\ is\ provided\ by\ vehicle\ type\ i\ from\ hub\ j;\ 0, else$

z_j: $1, if\ hub\ j\ is\ built;\ 0, else$

With the notation presented, the MILP for hub network generation, corresponding heterogeneous fleet assignment, and route estimation is formulated as follows:

$$\text{Min} = \sum_{j=1}^{J}\Big(z_j \cdot \big(h_j \cdot a + c\big)\Big) + \sum_{i=1}^{I}\sum_{j=1}^{J}\big(f_{i,j} \cdot v_i^{fix}\big) + o \cdot \left(\sum_{i=1}^{I}\big(q_i \cdot (v_i^{ope} + v_i^{ext})\big) + (t \cdot w)\right) \tag{1}$$

$$z_j \geq y_{i,j,k} \qquad \forall\, i,j,k \tag{2}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J} y_{i,j,k} \geq 1 \qquad \forall\, k \tag{3}$$

$$f_{i,j} \leq q_i \cdot F_i \qquad \forall\, i,j \tag{4}$$

$$q_i \leq r_i \cdot \sum_{j=1}^{J}\big(f_{i,j}\big) \qquad \forall\, i \tag{5}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K}\big(y_{i,j,k} \cdot d_k \cdot \bar{n}\big) \leq \sum_{i=1}^{I}\big(f_{i,j} \cdot m_i\big) \qquad \forall\, j \tag{6}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K}\big(u_{j,k} \cdot y_{i,j,k} \cdot l_i\big) \leq \sum_{i=1}^{I}\big(f_{i,j} \cdot r_i\big) \qquad \forall\, j \tag{7}$$

$$\sum_{i=1}^{I}\sum_{k=1}^{K}\big(y_{i,j,k} \cdot d_k \cdot \bar{n}\big) \leq s \qquad \forall\, j \tag{8}$$

$$f_{i,j} \leq z_j \cdot F_i \qquad \forall\, i,j \tag{9}$$

$$\sum_{k=1}^{K} d_k \leq T \cdot \sum_{i=1}^{I}\sum_{j=1}^{J}\big(f_{i,j} \cdot b_i\big) \tag{10}$$

$$u_{j,k} \cdot y_{i,j,k} \leq U \qquad \forall\, i,j,k \tag{11}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\big(f_{i,j} \cdot e_i\big) \leq E \cdot \sum_{i=1}^{I}\sum_{j=1}^{J}\big(f_{i,j}\big) \tag{12}$$

$$q_i = \sum_{j=1}^{J}\sum_{k=1}^{K}\big(u_{j,k} \cdot y_{i,j,k} \cdot l_i\big) \qquad \forall\, i \tag{13}$$

$$t = T \cdot \sum_{i=1}^{I}\sum_{j=1}^{J} f_{i,j} \tag{14}$$

$$\sum_{i=1}^{I}\big(f_{i,j} \cdot g_i\big) \leq p_j \qquad \forall\, j \tag{15}$$

$$Q \cdot \sum_{j=1}^{J} f_{i,j} \leq q_i \qquad \forall\, i \tag{16}$$

$$y_{i,j,k}, z_j \in \{0, 1\} \qquad \forall\, i, j, k \tag{17}$$

$$f_{i,j}, q_i, t \geq 0 \qquad \forall\, i, j \tag{18}$$

The objective function (1) minimizes the sum of resulting hub operation, (fixed, operational, and external) vehicle, and personnel costs. Constraints (2) and (3) secure the correct assignment of demand location to hubs. Constraints (4) and (5) ensure the allocation of vehicles to customers. The observance of vehicle related thresholds (transport capacity and range) is guaranteed by constraints (6) and (7). Constraints (8), (9), and (10) secure the limits regarding the container capacity, the number of vehicles per hub, and the working times of employees. The maximum allowed distance between a hub location and its assigned demand locations and the emission limit of the whole fleet are restricted by constraints (11) and (12). Constraints (13) and (14) are used to calculate the covered distances and delivery times required. Parking space limits at hubs are restricted in constraint (15), while constraint (16) secures vehicles to cover a minimum distance to guarantee balanced routes. Constraints (17) and (18) define the value range of the decision variables.

7.3. Decision Support System

The mathematical model forms the basis for the developed DSS. The DSS, which is adapted from the DSS for carsharing network optimization of Sonneberg et al. (2015), provides decision support for optimal placement of mobile hubs and related fleet assignments. It enables decision makers without optimization knowledge to run desired scenarios. With datasets (including potential hub locations and demand locations) imported and parameters (for network, vehicle, and city characteristics) adjusted, the optimization starts by triggering the corresponding optimize button. An include file is created containing all information and values entered. Once the generation of the input file is complete, the software *GAMS*, in combination with the solver *IBM ILOG CPLEX*, start the optimization automatically. After completion, the results are written to respective files in form of deployed stations and the corresponding vehicle allocation. For a visual representation within a web browser, the results can be exported via *JavaScript* by using the *Google Maps API*. The resulting system architecture, the data flow, and the GUI are shown in Figure 30.

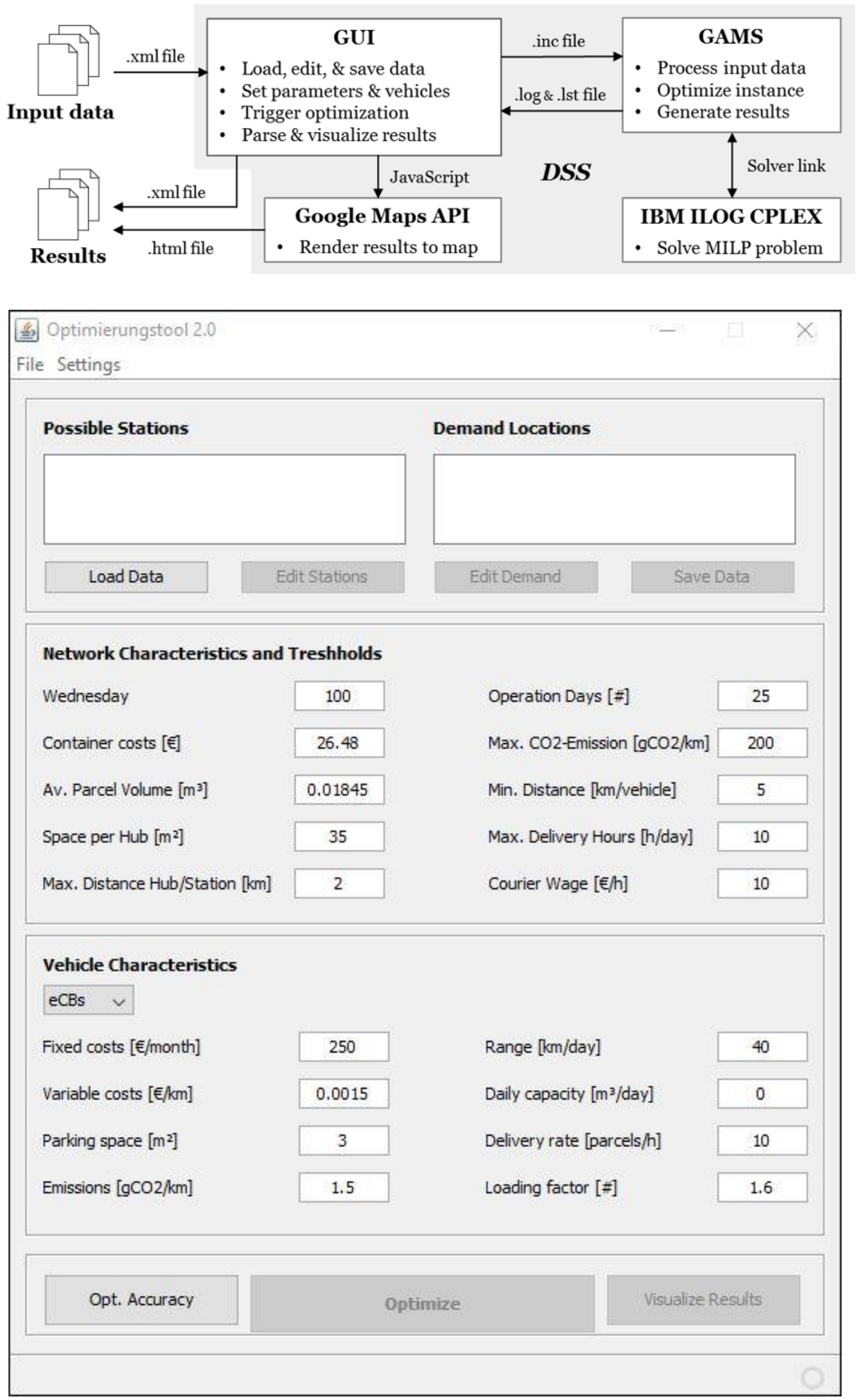
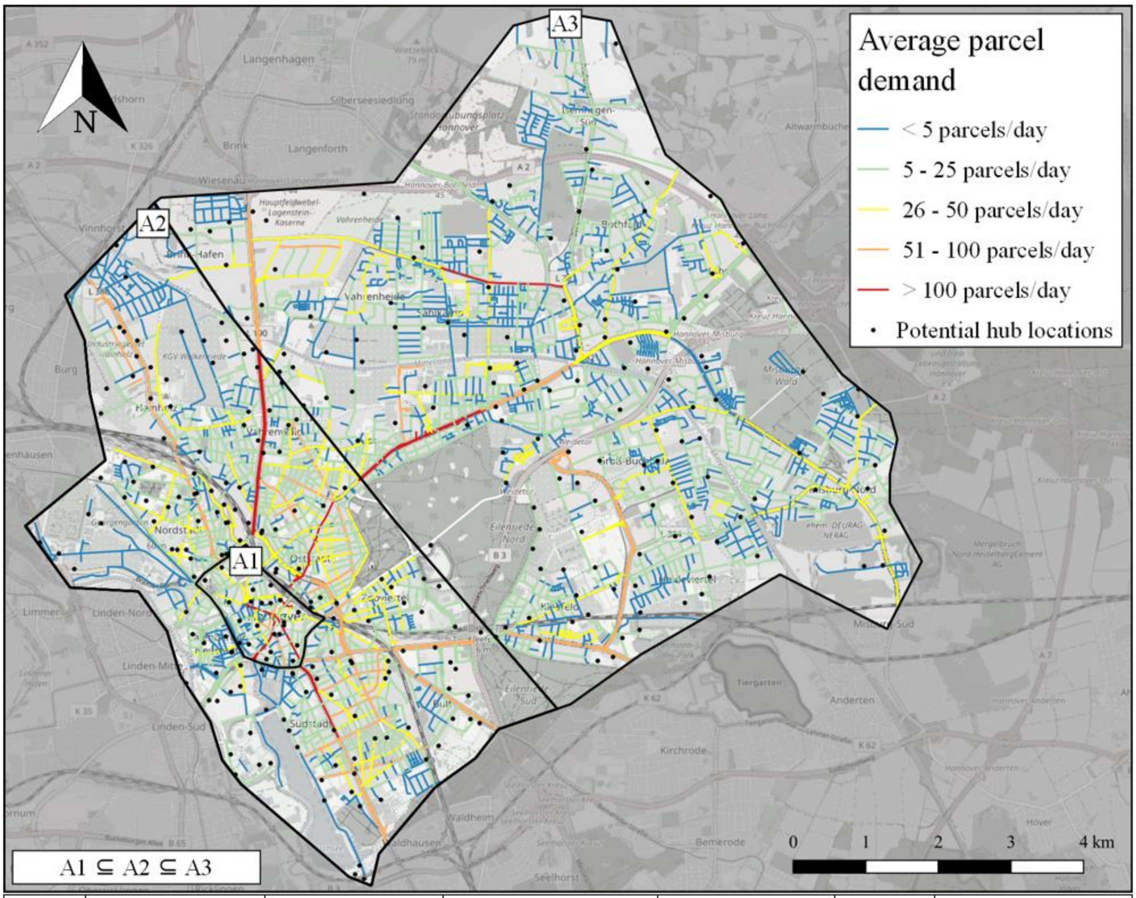


Figure 30. System Architecture (top) and GUI (below) of the DSS; Based on Leyerer et al. (2019b).

7.4. Application Example and Discussion of Results

To evaluate the DSS and the underlying optimization model, benchmark calculations are provided for the city of Hannover. Hannover is a mid-sized city with a total population of more than 500,000 inhabitants. Figure 31 presents characteristics of the city structure and introduces three investigation areas. Area A1 reflects the inner city center. Area A2 contains area A1 and densely populated urban surroundings. Area A3 is a further extension with a total of 1,662 demand (differently colored on street level) and 339 potential hub locations (black dots). Each area is further defined by its average daily parcel demand, size, number of inhabitants, and corresponding population density.



Area	Demand locations [#]	Potential hub locations [#]	Average daily parcel demand [#]	Inhabitants [#]	Space [ha]	Inhabitants per area [#/ha]
A1	102	58	1,842	7,032	151.2	46.5
A2	717	209	8,772	192,766	3,139.6	61.4
A3	1,662	339	16,738	350,249	8,874.1	39,5

Figure 31. Considered Investigation Area and Characteristics; Based on Leyerer et al. (2019b).

To allow for a heterogeneous fleet, various kinds of vehicles are implemented in this application example, namely electric cargo bicycles (eCB), electric cargo tricycles (eCT), cars (Car), electric cars (eCar), light-duty vans (Van), and electric light-duty vans (eVan).

These vehicles dispose of different fixed and variable costs, delivery rates, ranges, and emissions, with respective values based on manufacturer's specifications. Larger vehicles are able to deliver more parcels per trip due to higher capacity. This also applies for fixed and variable expenses. An electric propulsion system requires higher initial investment, whereas operative costs are lower compared to a conventionally powered vehicle. To address the different negative impacts of transport vehicles, externalities in terms of emissions, noise, and congestion are considered. Emissions are regarded as local tailpipe emissions and not as well-to-wheel emissions that would include the energy consumption during manufacturing process. In addition to vehicle characteristics, further parameters regarding hub costs and spaces, delivery hours and wages, and minimum distances between demand and hub locations are set. With a standard notebook (Intel Core i7, 2.5 GHz, 16 GB RAM), the software *GAMS 24.5.6* in combination with the solver *IBM ILOG CPLEX 12.6.2.0*, and preset optimization gap of 1%, the results for the different areas are obtained in Table 8. It contains the elements total costs, number of established hubs, fleet composition, approximated distances covered, and resulting local CO_2-emissions.

Table 8. Comparison of Different Areas; Based on Leyerer et al. (2019b).

Area	Total costs [€/month]	Used hubs [#]	Used vehicles [#]							Approx. distance covered [km/day]			Total emissions [gCO_2/day]	Average emissions of vehicle fleet [gCO_2/km]
			eCB	*eCT*	*Car*	*eCar*	*Van*	*eVan*	∑	Diesel driven	Electric driven	∑		
A1	35,793	7	1	-	-	-	11	-	12	55.1	6.4	61.5	11,021	179.3
A2	187,465	37	2	-	-	-	60	-	62	300.2	11.9	312.1	60,038	192.3
A3	317,102	53	1	-	-	-	104	-	105	520.0	7.9	527.9	104,000	197.0

With a wider operation area, higher monthly costs result due to a rising number of parcels to be delivered. For successful delivery, the network has to consist of more stations and transport vehicles. As emission limits are not bounding the optimization, all scenarios apply only eCBs and conventionally powered Vans. For A1 61.5 km are required for delivery purposes, in A3 527.9 km are needed to satisfy the customers' demand. This increase is also reflected for total emissions emitted. Proportionally, the one eCB in A1 covers more kilometer instead of the one (two) for A3 (A2) resulting in a lower value of average fleet emissions. Regarding the costs per parcel, values of 0.810 € for A1, 0.890 € for A2, and 0.789 € for A3 result. The computation time amounts to 2.1 minutes for A1, 2.2 hours for A2, and 5.5 hours for A3 reflecting the NP-hardness of the underlying MILP.

Table 9. Benchmarks for Different CO_2-Emission Levels for A2; Based on Leyerer et al. (2019b).

Max. CO_2-level [gCO_2/km]	Total costs [€/month]	Used hubs [#]	Used vehicles [#]							Approx. distance covered [km/day]			Total emissions [gCO_2/day]	Average emissions of vehicle fleet [gCO_2/km]
			eCB	*eCT*	*Car*	*eCar*	*Van*	*eVan*	∑	Diesel driven	Electric driven	∑		
200	187,465	37	2	-	-	-	60	-	62	300.2	11.9	312.1	60,038	192.3
150	189,156	36	19	-	-	-	48	-	67	240.0	121.0	361.0	48,000	133.0
100	191,242	27	37	-	-	-	36	-	73	180.1	187.5	367.6	36,027	98.0
50	195,819	33	51	-	2	-	18	6	77	115.2	341.3	456.5	20,820	45.6
0	199,091	21	54	2	-	-	-	22	78	-	467.4	467.4	0	0.0

To investigate the influence of stepwise decreasing CO_2-emission values, A2 is chosen as basic scenario in Table 9. The first column of 200 gCO_2/km represents results equal to those stated in Table 8 as CO_2-emissions are not limited. Regarding the cost-to-capacity ratio, the Van exhibits the lowest values. Decreasing the maximum permitted emissions leads to an increase of vehicles and costs. This can be explained by the gradual substitution of conventionally powered Vans by eCBs (lower capacity) and eVans (higher fixed costs). The number of used hubs is influenced by space restrictions of deployed vehicles. Larger vehicles (at most established at a level of 200 gCO_2/km) require more parking space compared to smaller vehicles in the scenario 0 gCO_2/km. The total distance travelled increases with lower CO_2-thresholds due to the described fleet structure substitution and smaller delivery vehicles assigned that dispose a lower transport capacity (eCBs and eCTs). Based on the vehicle deployment, the CO_2-limits are almost completely exploited. Investigating the total costs of emission-limiting measures, a total avoidance of local CO_2-emissions leads to an increase in costs of € 11,625.85 per month (+6.2%) compared to the unrestricted scenario. Based on these benchmarks, alternative transport vehicles, e.g., eCBs, should be integrated into the fleet when aiming for CO_2-free or -reduced urban LMD with hubs.

As previous scenarios permit heterogeneous fleets, following benchmarks focus on the impacts of solely one vehicle type (Figure 32) applying stacked columns for different cost types. To allow for corresponding homogeneous fleets, emission-constraints are not implemented. Regarding overall costs, a conventional powered Van-fleet is most cost-efficient due to their high transport capacity resulting in the fewest number of vehicles and corresponding delivery men (187,615.10 €/month). This is also the case for an eVan-fleet depicting the second-lowest overall costs. If applying smaller transport vehicles, costs rise trough additionally required vehicles and couriers. Consequently, in case of a pure eCB-fleet, the highest overall costs incur (444,007.15 €/month). Investigating the cost components, personnel costs account for the largest share of total costs for all vehicle types. In case of a pure eCB-fleet, wage costs for couriers amount to 86.9% of the overall costs. In contrast, fixed vehicle costs are least expensive for an eCB-fleet (11.3%) and highest for an eVan-fleet (38.3%). Due to low distances travelled, operational and external vehicle costs have only a minor influence on costs, which is also the case for hub-costs. If a CEP service provider wants to achieve a cost-efficient homogeneous fleet without producing local emissions, an eVan-fleet should be installed (210,642.45 €/month). Comparing the cargo cycles, eCTs are more preferable in contrast to eCBs as they entail significantly lower total costs (-30.01%). Cars, irrespective of propulsion method, are not competitive, as Vans and even eVans exhibit lower total costs. When analyzing the obtained results of pure fleets in contrast to the heterogeneous ones of Table 9, it becomes clear that a mixed fleet is beneficial for CEP service providers. Due to the different vehicle specifications, respective cost-specific advantages and disadvantages can be compensated against each other.

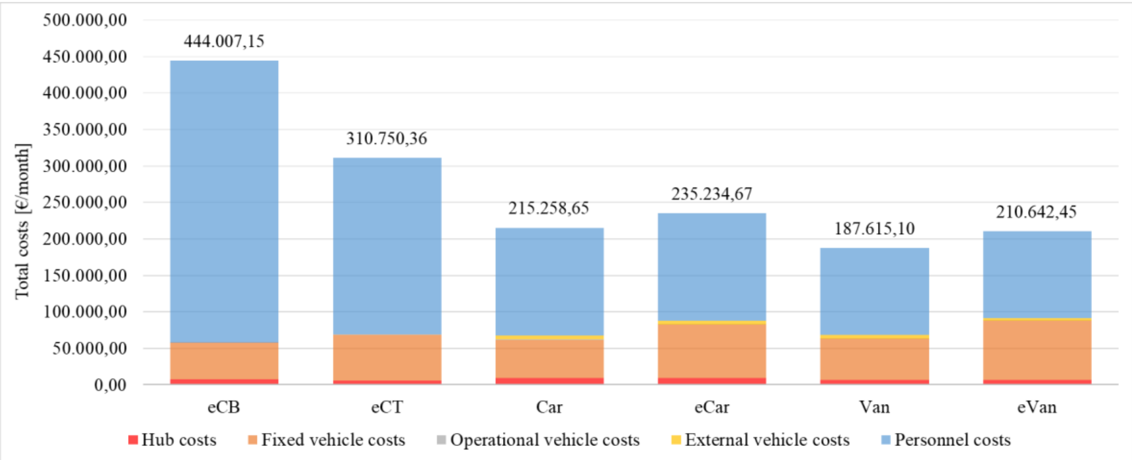


Figure 32. Benchmarks for Sole Use of Vehicle Types for A2; Based on Leyerer et al. (2019b).

7.5. Contributions, Limitations, and Future Research

The approach contributes to a more sustainable LMD towards urban parcel deliveries. Existing scientific literature is expanded by providing an optimization model and a corresponding DSS to minimize costs. The model focuses on the establishment of micro-hubs that allows for shorter LMD enabling the application of alternative transport vehicles, e.g., cargo cycles. Considering road traffic, noise, and air pollution together with local CO_2-emissions, negative externalities are reduced by corresponding settings depicting an improvement concerning research on green and sustainable commercial freight transport. By exploitation of the user-friendly DSS, CEP service providers, policy makers, and other relevant planners are supported in finding appropriate solutions for the urban delivery of goods to meet potential forthcoming regulations. The DSS was tested and evaluated on several benchmarks. In doing so, recommendations and implications were presented to facilitate better decision making.

Nevertheless, there are limitations and enhancement opportunities to be mentioned. To simplify real-world conditions, the optimization model is based on several assumptions. Regarding the parcels, a delivery rate of 100% is set. In reality, some parcels cannot be delivered successfully at first attempt. These parcels have to be stored at established hubs for the next operating day. A surcharge as safety factor should be deliberated for the delivery rate as well as the parcel storage space at hubs. Additionally, a certain range of sizes and corresponding weights could be implemented. This would probably change the fleet composition as small and lightweight parcels would be delivered by cargo cycles and others by (e)Vans. Future research should focus on a more realistically delivery rate and a diversified parcel structure instead of uniform packages. Further, varying delivery speeds for different transport vehicles have to be mentioned as limitation as it directly influences personnel costs. For travel distance approximation, the choice of Euclidean distances has to be discussed, especially for American cities with symmetric block structure. The consideration of one-way roads, road parking limitations, and other restrictions have different influences for the implemented vehicles types. These elements are part of operative planning, where a detailed sequencing of customers is optimized and not estimated as in the tactical approach on hand. An efficient routing approach is crucial for success of the tactical hub establishment and fleet assignment. In general, the recommendation provided by the developed DSS has to be compared by the user to present expertise and prevailing conditions. However, additional research on the proposed concept and its impact is required. Further, the installed hubs could additionally be used as pick-up points for customer self-collection to lower commercial distances travelled. In terms of methodology, the approach provides a solution-oriented artifact that is positioned within the domain of Green IS. Through self-explanatory use of the DSS, savings in terms of environmental and economic sustainability are enabled. As suggested for DSR, a holistic field test is missing in terms of validation, which should be part of future research.

8. Parcel Delivery Optimization with Autonomous Robots

8.1. Academic Classification

This section refers to the article "Autonomous Unmanned Ground Vehicles for Urban Logistics: Optimization of Last Mile Delivery Operations" (Sonneberg et al. 2019a and Appendix L). The article was a collaboration of Marc-Oliver Sonneberg, Max Leyerer, Agathe Kleinschmidt, Florian Knigge, and Michael H. Breitner and submitted to the 52nd Annual Hawai'i International Conference on System Sciences (HICSS) 2019 in Grand Wailea (Maui, Hawaii, USA). A double-blind peer-review process with one revision round (two reviewers and one track chair) preceded the acceptance for the article presentation at the conference and the publication in the conference proceedings. The article was assigned to the mini-track "Intelligent Decision Support and Big Data for Logistics and Supply Chain Management" of the track "Decision Analytics, Mobile Services, and Service Science". HICSS is the longest-standing working scientific conference for IS and IT research worldwide and the top IS conference in terms of citations as recorded by *Google Scholar* (HICSS, 2020). The proceedings of the HICSS are classified "B" by WKWI and received the rating "C" in the JQ3. The article is part of the project *USEfUL* (grant number: 03SF0547) and was funded by the *German Federal Ministry of Education and Research* (BMBF). *The following section 8 is largely based on Sonneberg et al. (2019a).*

8.2. Problem Description and Optimization Approach

The presented approach addresses a concept for urban commercial freight transport that relies on today's ICT. As road space and pollution are becoming a major problem in cities, alternative delivery modes are under investigation. A possibility to reduce these problems are autonomous delivery robots, also referred to as autonomous unmanned ground vehicles (AUGV). AUGV move autonomously within public space on footpaths relieving stressed road networks (Ullrich, 2015). Compared to traditional delivery vehicles, AUGV are restricted in terms of parcel storage and range due to small accumulators for electric propulsion integrated. Despite these restrictions, AUGV provide a useful solution, especially for same-day or even instant deliveries, which are becoming increasingly relevant in e-commerce. AUGV are able to assist the LMD of small goods depicting an option to save personnel expenses, road space, emissions, and noise, but are not capable of solving the present problems completely. Delivery robots are assigned to existing stations, e.g., parcel service points, where they are loaded. Today, there are only few manufacturers of AUGV. Within several projects, the application of an autonomous delivery was tested in cooperation with different companies, e.g., the robot of *Starship Technologies* in case of traditional small parcels, prepared dishes, e-groceries, or medicine products (Starship Technologies, 2020).

When assigning delivery robots to stations and optimizing routes, a LRP approach is able to solve these elements simultaneously. Several optimization models focus on autonomous vehicles in urban logistics concepts. Regarding the tactical facility planning of autonomous unmanned aerial vehicles (AUAV) for delivery purposes, Shavarani et al. (2015) determine the optimal number of stations, while routes are not investigated. Murray and Chu (2015) introduced a VRP for the optimization of AUAV minimizing aerial delivery time based on a set of existing stations and drones. Other VRP approaches focus on concepts that combine traditional parcel deliveries by vans or trucks with autonomous vehicle modes to maximize the delivery efficiency. Such approaches for tandem delivery of van and AUAV are presented by Agatz et al. (2018), Carlsson and Song (2017), and Ferrandez et al. (2016) or for the case of AUGV by Boysen et al. (2018). However, the provision of decision support by means of VRP or LRP for sole application of AUGV are not existent in scientific research. To address this lack, the following research question is investigated:

How can an IS support the establishment of an urban delivery network for route planning using autonomous unmanned ground vehicles?

To answer the research question, a MILP for simultaneous optimization of station selection in terms of number and location, related customer assignment to stations, number of AUGV, and tours as well as corresponding routes was developed. The following assumptions form the basis of the model.

Demand levels and locations of the customers are given and have to be served by at least one vehicle. The demand is characterized as a certain number of uniform packages per customer. Parcels are delivered within the desired customer time window, undeliverable shipments and multiple delivery attempts do not exist. Potential stations with sufficient space for short-term storage and charging infrastructure for recharging purposes are existent, identical equipped AUGV are directly assigned to a station. An AUGV dispose a certain number of separated compartments, each of which is able to carry one uniform package. A delivery robot is able to conduct several tours per day, split deliveries are possible. Preparing time for shipment loading and, if necessary, recharging time of the accumulator occurs. With the help of the following notations, the subsequent MILP is developed.

Sets:

$g, h \in \mathcal{G}: locations\ /\ graph\ nodes$

$i, l \in I \subseteq G: customers\ demand\ locations$

$j \in J \subseteq G: potential\ stations$

$k, o \in K: tours$

$r \in R: potential\ delivery\ robots$

Parameters:

a_i: $demand\ of\ customer\ i$ [#]

b^{range}: $maximum\ battery\ electric\ range\ of\ a\ delivery\ robot$ $[km]$

b^{time}: $maximum\ battery\ operating\ time\ of\ a\ delivery\ robot$ $[min]$

c: $transport\ costs\ per\ distance\ unit$ $[€/km]$

d_{gh}: $distance\ between\ location\ g\ and\ h$ $[km]$

e: $auxiliary\ parameter$

f: $rental\ fee\ per\ delivery\ robot$ $[€/day]$

M: $sufficiently\ large\ number$

n: $number\ of\ minutes\ of\ a\ time\ interval$ $[min]$

p: $personnel\ costs\ per\ minute$ $[€/min]$

$q_j^{station}$: $storage\ capacity\ of\ station\ j$ [#]

q^{robot}: $number\ of\ a\ delivery\ robot's\ compartments$ [#]

s^{range}: $safety\ buffer\ for\ the\ battery\ electric\ range$ $[km]$

s^{time}: $safety\ buffer\ for\ the\ battery\ operating\ time$ $[min]$

t^{load}: $loading\ time\ per\ shipment$ $[min]$

t^{serv}: $service\ time\ per\ customer$ $[min]$

t_{gh}^{time}: $travel\ time\ from\ location\ i\ to\ g$ $[min]$

v_j^{close}: $closing\ time\ of\ station\ j$

v_j^{open}: $opening\ time\ of\ station\ j$

w_i^{close}: $latest\ possible\ delivery\ time\ of\ customer\ i$

w_i^{open}: $earliest\ possible\ delivery\ time\ of\ customer\ i$

Decision Variables:

α_{ghk}: $1, if\ tour\ k\ leads\ from\ location\ g\ to\ location\ h; 0, else$

β_{rj}: $1, if\ robot\ r\ is\ located\ at\ station\ j; 0, else$

γ_j: $1, if\ a\ station\ is\ selected\ at\ location\ j; 0, else$

$\delta_{gk}: arrival\ time\ of\ tour\ k\ at\ location\ g$

$\varepsilon_{ijk}: compartments\ of\ station\ j\ in\ tour\ k\ to\ customer\ i$

$\zeta_{kr}: 1, if\ tour\ k\ is\ driven\ by\ robot\ r;\ 0, else$

With the notation presented, the MILP for station selection, AUGV assignment, tour, and route planning is formulated as follows:

$$Min = \sum_r \rho_r * f + \sum_i a_i * t^{load} * p + \sum_g \sum_h \sum_k d_{gh} * c * \alpha_{ghk} \quad (1)$$

$$\sum_j \sum_k \varepsilon_{ijk} = a_i \qquad \forall\ i \quad (2)$$

$$\varepsilon_{ijk} \leq y_{ik} * M \qquad \forall\ i, j, k \quad (3)$$

$$\varepsilon_{ijk} \leq y_{jk} * M \qquad \forall\ i, j, k \quad (4)$$

$$\sum_k y_{ik} \leq \left({a_i}/{q^{robot}} \right) + 1 - e \qquad \forall\ i \quad (5)$$

$$\sum_h \alpha_{ghk} = y_{gk} \qquad \forall\ g, k \quad (6)$$

$$\sum_g \alpha_{ghk} = y_{hk} \qquad \forall\ h, k \quad (7)$$

$$u_{lk} - u_{ik} + |\mathcal{I}| * \alpha_{lik} \leq |\mathcal{I}| - 1 \qquad \forall\ i, l, k; i \neq l \quad (8)$$

$$\alpha_{ggk} = 0 \qquad \forall\ g, k \quad (9)$$

$$\sum_i \sum_j \varepsilon_{ijk} \leq q^{robot} * \sum_r \zeta_{kr} \qquad \forall\ k \quad (10)$$

$$\sum_r \zeta_{kr} \leq 1 \qquad \forall\ k \quad (11)$$

$$\sum_k \zeta_{kr} = \sum_k \sum_o \lambda_{kor} + 1 \qquad \forall\ r \quad (12)$$

$$\lambda_{kkr} = 0 \qquad \forall\ k, r \quad (13)$$

$$\sum_k \lambda_{kor} \leq \zeta_{or} \qquad \forall\ o, r \quad (14)$$

$$\sum_o \lambda_{kor} \leq \zeta_{kr} \qquad \forall\ k, r \quad (15)$$

$$\mu_k = \sum_i \sum_g \left(t^{serv} + t_{ig}^{time} \right) * \alpha_{igk} + \sum_j \sum_h t_{jh}^{time} * \alpha_{jhk} \qquad \forall\ k \quad (16)$$

$$\delta_{jk} \leq \delta_{jo} - \mu_o - t^{load} + (1 - \lambda_{kor}) * M \qquad \forall\ j, k, o, r; k \neq o \quad (17)$$

$$\sum_i \sum_k \varepsilon_{ijk} \leq q_j^{station} * \gamma_j \qquad \forall\ j \quad (18)$$

$$\sum_{j} \beta_{rj} = 1 \qquad \forall\, r \tag{19}$$

$$\zeta_{kr} - (1 - y_{jk}) \leq \beta_{rj} \qquad \forall\, j,k,r \tag{20}$$

$$\sum_{k} \zeta_{kr} \leq \rho_r * M \qquad \forall\, r \tag{21}$$

$$\sum_{g} \sum_{h} d_{gh} * \alpha_{ghk} \leq b^{range} - s^{range} \qquad \forall\, k \tag{22}$$

$$\mu_k \leq b^{time} - s^{time} \qquad \forall\, k \tag{23}$$

$$\delta_{ik} \geq w_i^{open} \qquad \forall\, i,k \tag{24}$$

$$\delta_{ik} \leq w_i^{close} \qquad \forall\, i,k \tag{25}$$

$$\delta_{gk} \geq \delta_{ik} + t^{serv} + t_{ig}^{time} - (1 - \alpha_{igk}) * M \qquad \forall\, g,i,k \tag{26}$$

$$\delta_{gk} \leq \delta_{ik} + t^{serv} + t_{ig}^{time} - (1 - \alpha_{igk}) * M \qquad \forall\, g,i,k \tag{27}$$

$$v_j^{open} + t_{ji}^{time} - \delta_{ik} - (1 - \alpha_{igk}) * M \leq 0 \qquad \forall\, i,j,k \tag{28}$$

$$\delta_{jk} \leq v_j^{close} \qquad \forall\, j,k \tag{29}$$

$$\alpha_{ghk}, \beta_{rj}, \gamma_j, \zeta_{kr}, \lambda_{kor}, \rho_r, y_{gk} \in \{0,1\} \qquad \forall\, g,h,i,j,k,o,r \tag{30}$$

$$\delta_{gk}, \mu_k, u_{gk} \geq 0 \qquad \forall\, g,k \tag{31}$$

$$\varepsilon_{ijk} \in \mathbb{Z}_{\geq 0} \qquad \forall\, i,j,k \tag{32}$$

The objective function (1) minimizes the total costs of one working day. It consists of AUGV rental costs, personnel costs for shipment preparation, and variable distance costs for all tours. Constraints (2) to (9) refer to the classical VRP constraints for demand assignment to stations as well as corresponding route planning. The assignment of AUGV to tours and their duration is calculated in constraints (10) to (17). Constraints (18) to (21) secure the correct assignment of AUGV to stations. Safety buffers in terms of delivery time and distance are part of constraints (22) and (23). Constraints (24) to (29) ensure the observance of time windows of customers and stations as well as the correct tour planning in terms of loading and service time for shipment preparation at the station and following delivery. Constraints (30), (31), and (32) limit the value range of the corresponding decision variables.

8.3. Application Example and Discussion of Results

The calculation for this application example and the benchmarks were performed on a standard computer (Intel Core i5-6200 CPU, 2.30 GHz, and 8 GB RAM) using modeling software *GAMS 24.5.6* with the solver *IBM ILOG CPLEX 12.6.2.0*. The computation time is limited to 10,000 seconds and an optimization gap of 5% is set, while the majority of results were obtained in less than one minute.

Figure 33 illustrates the results of AUGV equipped with four compartments, 10 customers (vertical axis) to be served within their time windows (horizontal axis) and 20 shipments. Round marks present the tour number the goods are delivered as well as the related arrival times. As a result, one AUGV at one station is built to supply the customers with their shipments. Five tours with one recharging process accounts to 45.82 € per day. Thereof, 20 € are AUGV rental costs (43.65%), 10 € are personnel costs for preparing the robot (21.82%), and 15.82 € result through variable distance costs (34.53%).

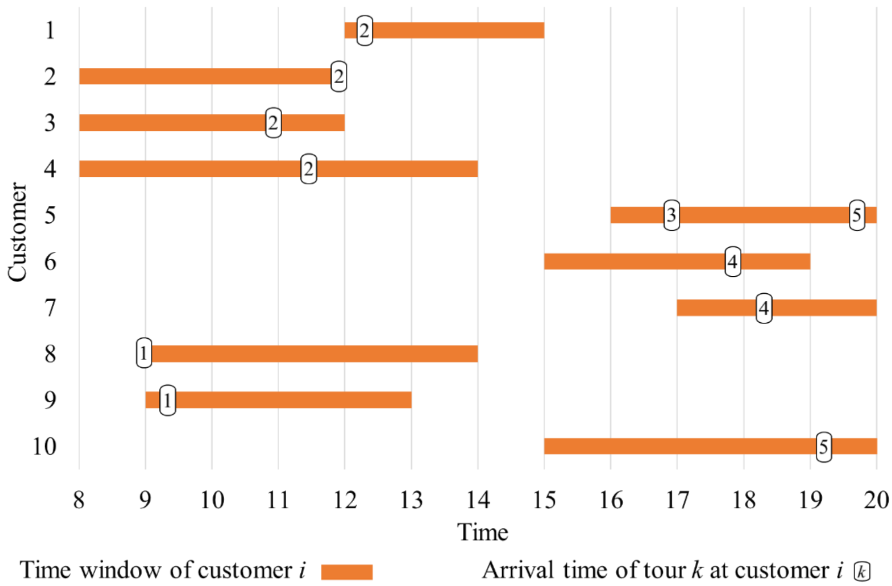


Figure 33. Customers' Time Windows and Arrival Times; Based on Sonneberg et al. (2019a).

To show the influences of the number of compartments per AUGV on distance and costs, related benchmarks are provided as illustrated in Figure 34. The vertical axis shows the total daily costs (left in blue) and the distance covered (right in green). When increasing the number of compartments, costs and distance decreases. Using two instead of one compartment, costs are reduced by approximately 46%, as fewer AUGV (one instead of three) are required for delivery by obtaining customers' time windows. When further increasing the number of compartments, costs savings are rather low. When focusing on the distances travelled, established AUGV with only one compartment conduct inefficient round-trips. This routing is even intensified in the case of customers demanding more than one shipment. The more customers can be supplied on a single tour, the more economies of scale will result and gradually reduce the distance covered. However, with a number of compartments of more than four, this effect decreases.

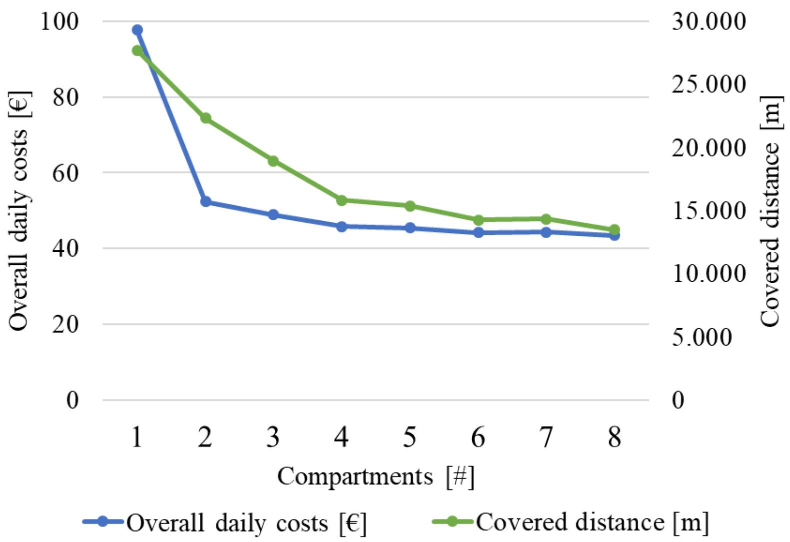


Figure 34. AUGV Compartment Benchmarks; Based on Sonneberg et al. (2019a).

As shown, the number of compartments depicts a crucial parameter for route planning with AUGV. Depending on the purpose, weight, and size of the shipments (e.g., prepared dishes, e-grocery, or the dispatch of medicines), the use of AUGV with multiple compartments is beneficial as several customers can be aggregated to one tour. Most AUGV manufacturers offer robots with only one compartment, which impede the efficient delivery of goods. The movement of AUGV on footpaths may hindered by overcrowded pedestrian zones or other obstacles. In terms of customer acceptance regarding autonomous delivery concepts with robots, positive projections are revealed (Joerss et al., 2016). As suggested by Boysen et al., (2018), AUGV could be used in combination with conventional delivery vehicles to optimize parcel deliveries. However, AUGV do not represent an all-encompassing solution to existing problems in urban logistics.

8.4. Contributions, Limitations, and Future Research

The introduced approach contributes to solutions for a more sustainable urban LMD by investigating small-sized deliveries via delivery robots. These are able to transport special shipments promoting new business models for urban delivery, e.g., same-day or same-hour deliveries. By applying this concept, personnel expenses can be reduced, road space relieved, and noise as well as emissions decreased. Existing knowledge on LRP approaches is expanded with focus on urban delivery. In doing so, computer-aided decision support is enabled for parcel service providers, city authorities, and other (potential) stakeholders in finding optimal solutions for their underlying business case. As a result, the approach contributes to Green IS addressing locally emission free supply of goods for enhanced economic and environmental sustainability.

Concerning limitations, the model formulation as LRP can only be used for simultaneous station location and route planning. When using such a concept with fixed parcel service points, a daily relocation of stores and corresponding robot assignment is not recommended. If applying depots in form of containers, which could be repositioned daily based on demand variations, the model could be effectively used. Yet, it is also possible to fixate selected stations to circumvent station planning, which would result in an adjusted VRP. In case of increasing demands for AUGV deliveries, the model can also be used for network expansion reasons. In reality, parcel shipments differ widely in terms of weight and dimension. In this approach, this fact is not considered as uniform packages are modeled. For route planning, Euclidean distance measurement was applied, which is only limited suitable for real applications in urban logistics. Actual traffic data can be obtained from web-based traffic and map providers offering API. The developed mathematical model is classified as NP-hard problem. With increasing problem size, the required computation time increases exponentially. Thus, optimal solutions for large instances are not achievable within a reasonable amount of time. The calculations presented in this context are based on a small problem size with fictive demand levels for parcels. The decision maker must pay attention in terms of value setting regarding the distance-related customer to station assignment or too narrow customer time windows that can lead to infeasibility. Based on the input values chosen, an optimization process may require several hours to find a useful solution. Further research should focus on the concept and its impacts itself, the limitations mentioned, further analyses on larger problem instances, and the development of a more efficient heuristic solution procedure. For final validation, a field test would lead to better planning, optimization, and decision support.

9. Optimization of E-Grocery Deliveries

9.1. Academic Classification

This section is based on two consecutive research articles. The first article has the title "Decision Support for Urban E-Grocery Operations" and was contributed by Max Leyerer, Marc-Oliver Sonneberg, and Michael H. Breitner (Leyerer et al., 2018 and Appendix J). The article was accepted and presented after a double-blind peer review (two reviewers and mini-track chair) with one revision within the mini-track "Information Systems for Sustainable and Resilient Businesses and Supply Chains" of the track "Green IS and Sustainability" at the 24th Americas Conference on Information Systems (AMCIS) 2018 in New Orleans (Louisiana, USA). The AMCIS is described as one of the leading conferences for presenting and discussing IS/IT research (AIS, 2020b). Among more than 300 completed papers featured, our article was honored as best paper in track as well as overall best paper of AMCIS 2018 (AIS, 2018). Finally, the article was published in the corresponding proceedings of the 24th AMCIS, classified "D" in the JQ3 and "B" in the WKWI-rating. The article is part of the project *USEfUL* (grant number: 03SF0547B) and was funded by the *German Federal Ministry of Education and Research* (BMBF).

Based on discussions with leading academics at the AMCIS, the article was substantially enhanced. Areas of improvement were the classification into scientific literature, the mathematical model, the computational study, a comparison of the proposed concept to conventional delivery of online ordered groceries, and discussions including managerial implications. The resulting article named "Shortening the Last Mile of E-Grocery: Optimizing a new Logistics Concept for Urban Areas" was submitted to the special issue called "Smart Cities and Data-driven Innovative Solutions" of the non-rated open access journal Smart Cities (Leyerer et al., 2020 and Appendix V). *The following section 9 is largely based on Leyerer et al. (2018) and Leyerer et al. (2020).*

9.2. Problem Description and Optimization Approach

The approach discussed in this section introduces a concept for urban commercial freight transport of online ordered groceries, so called e-groceries. Groceries comprise food, household items, and other fast-moving consumer goods and possess different requirements regarding the cooling chain (e.g., temperature zones frozen, refrigerated, and dry). Customers select their desired goods and place them in the virtual shopping cart. By use of specialized transport vehicles that can handle respective temperature requirements, the goods are delivered to the customers' homes within desired time windows (Hübner et al., 2016). As a part of e-commerce, e-grocery represents a rising market. China (50.9$bn) and the USA (23.9$bn) have the largest e-grocery market sizes, while in Germany the share of e-grocery compared to overall grocery shopping is around 0.5% (IGD, 2018). Until 2023, in several countries, including Germany, China, and USA as well present shares are forecasted to double. These rising numbers can be explained by advantages in terms of independence of business hours or location, significant gains in time, greater flexibility, and product diversity. An increasing number of suppliers take part on the e-grocery upswing. These are differentiated between multi-/omni-channel retailer or by pure online players (Wollenburg et al. 2018). Accordingly, there are various advantages and disadvantages with regard to the picking process, delivery conditions, and product selection. Crucial factors for customer acceptance are delivery costs, punctual delivery, completeness, correctness, and product quality (Wollenburg et al. 2018). The same applies for CEP service providers. Some of these providers are integrating micro-depots within the city to allow for shorter urban routes and customer self-collection. First e-grocers begin to adapt those solutions by installation of refrigerated grocery lockers (Seidel et al., 2016). In the scientific body, the LMD optimization of e-groceries to end-customers is not yet properly examined. In their literature review on e-grocery, Mkansi et al. (2018) recommend to integrate transshipment points into the LMD, to use an eco-friendly heterogeneous vehicle fleet for the delivery, and to force customers to pick-up their orders on their own. To support the planning process of the described e-grocery concepts, the following research question is investigated:

How can an optimization model support the efficient design of a sustainable logistics concept for last mile deliveries of online ordered groceries?

The question is answered by development of an optimization approach that distributes refrigerated grocery lockers throughout the investigation area. An existing depot supplies the established stations. At these grocery lockers, customers can collect their orders themselves or receive them by means of ECB. To obtain faster computation times, the approach is separated into three consecutive stages. The overall optimization goal is to minimizing overall costs per day. Figure 35 illustrates the delivery concept and its optimization stages.

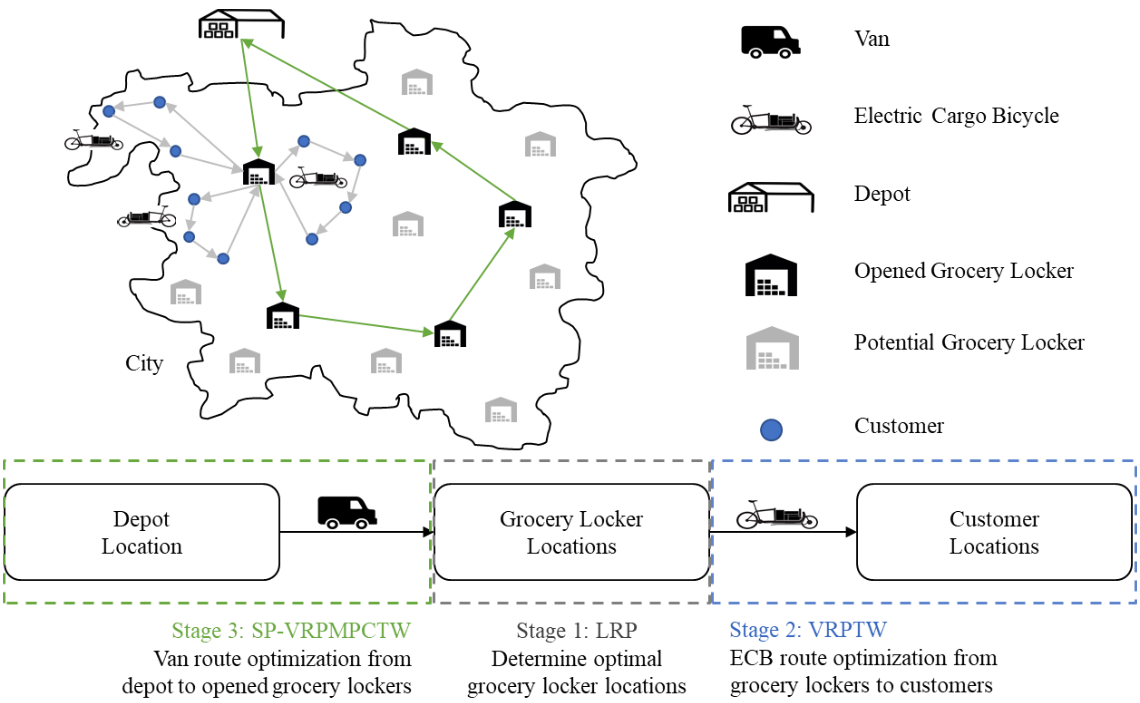


Figure 35. Overview of the Proposed E-Grocery Logistics Concept; Based on Leyerer (2020).

In the first stage, a LRP determines the optimal number, sizes, and locations of grocery lockers out of a set of potential locations. Further, the model assigns customers to established lockers and estimates required routes for depot to locker supply. Locker operating and transport costs are minimized. The second stage minimizes costs for routes from grocery lockers to the customers demanding home delivery within their desired time windows. The third step allows for route optimization of vans supplying the grocery lockers from the given depot. Transport costs are minimized while time windows, compartmentalized vehicles, and split-deliveries have to be observed. The following assumptions are subject to the multi-echelon optimization model.

The locations of customers and their demand levels differentiated by product types are given. Cooling chain requirements have to be observed, while the entire demand has to be satisfied. Within the investigation area, potential grocery locker locations are spread, varying per location in terms of costs. Lockers itself are subdivided into compartments to store the different product types based on cooling requirements. With a power connection available, a screen for storage and collection processes as well as a socket for ECB overnight charging operation is secured. When products are not self-collected by customers, the groceries are delivered via identical ECBs to customers' homes. ECB are directly assigned to grocery lockers. Cooling boxes are used to secure cooling chain requirements.

From a given depot, identical and compartmented vehicles (vans) supply grocery lockers. Different tours and split deliveries are permitted. Grocery lockers dispose of a latest possible fulfillment time to account for corresponding on-time ECB delivery to customers' homes. The following notation is used for the multi-echelon optimization model.

Sets:

$a, b, r \in \theta \cup S$: $nodes\ of\ the\ SP - VRPMPCTW$

$g, h, l \in N \cup M$: $nodes\ of\ the\ LRP\ and\ VRPTW$

$j \in J$: $grocery\ locker\ sizes$

$k \in K$: $ECB - tours$

$m \in M$: $potential\ locker\ locations$

$n \in N$: $customer\ nodes$

$p \in P$: $product\ types$

$s, \sigma \in S \subseteq M$: $opened\ grocery\ lockers$

$v \in V$: $van - tours$

$\beta, \phi \in \Omega \subseteq N$: $home\ delivery\ customers$

$\eta \in \Pi \subseteq N$: $elf - collection\ customers$

θ: $depot$

Parameters:

c^{ecb}: $average\ travelling\ cost\ per\ distance\ unit\ of\ an\ ECB$ $[€/km]$

c^{van}: $average\ travelling\ cost\ per\ distance\ unit\ of\ a\ van$ $[€/km]$

$d_{\beta p}$: $demand\ of\ home\ delivery\ customer\ \beta\ for\ product\ type\ p$ $[\#]$

$d_{\eta ps}$: $demand\ of\ self - collection\ customer\ \eta\ for\ product\ type\ p\ stored\ at\ grocery\ locker\ s$ $[\#]$

d_{np}: $demand\ at\ customer\ node\ n\ for\ product\ type\ p$ $[\#]$

F_{jm}: $costs\ for\ operating\ a\ grocery\ locker\ with\ size\ j\ at\ potential\ location\ m$ $[€]$

$\mathcal{M}$: $sufficiently\ large\ number$

o_{js}: $opened\ grocery\ lockers\ at\ location\ in\ locker\ size\ j$

Q^{ecb}: $capacity\ of\ an\ ECB$ $[\#]$

Q^{gl}_{jp}: $capacity\ of\ grocery\ locker\ size\ j\ for\ product\ product\ type\ p$ $[\#]$

Q^{van}_{vp}: $capacity\ of\ van - tour\ v\ for\ product\ type\ p$ $[\#]$

q_{sp}: $required\ quantity\ of\ product\ type\ p\ at\ opened\ grocery\ locker\ s$ $[\#]$

T^{min}_{β}: $start\ of\ time\ window\ for\ supplying\ customer\ \beta$

T^{max}_{β}: $end\ of\ time\ window\ for\ supplying\ customer\ \beta$

T^{min}_{a}: $start\ of\ time\ window\ for\ stowing\ at\ node\ a$

T^{max}_{a}: $end\ of\ time\ window\ for\ stowing\ at\ node\ a$

α: $maximum\ distance\ between\ a\ grocery\ locker\ and\ its\ assigned\ customers$ $[km]$

Δ^{ecb}_{gh}: $travel\ distance\ of\ an\ ECB\ between\ nodes\ g\ and\ h$ $[km]$

Δ_{ab}^{van}: *travel distance of a van between nodes a and b [km]*

$\bar{\Delta}^{ecb}$: *maximum allowed distance of an ECB − tour [km]*

$\bar{\Delta}^{van}$: *maximum allowed distance of a van − tour [km]*

δ_{gh}^{ecb}: *travel time of an ECB between nodes g and h [min]*

δ_{ab}^{van}: *travel time of a van between nodes a and b [min]*

τ: *average service time per customer [min]*

λ: *average handling time per product type per unit for stowing [min]*

Decision Variables:

o_{jm}: 1, *if locker size j is opened at locker location m*; 0, *else*

t_{av}: *arrival time at node a in van − tour v*

$t_{\beta k}$: *arrival time at customer β in ECB − tour k*

u_l: $l \in N$; *auxiliary variable to prevent short − trips between customers*

u_{rv}: $r \in S$; *auxiliary variable to prevent short − trips between grocery lockers*

x_{ghk}: 1, *if node g precedes node h in ECB − tour k*; 0, *else*

x'_{abv}: 1, *if node a precedes node b in van − tour v*; 0, *else*

y_{nm}: 1, *if customer n is assigned to locker location m*; 0, *else*

z_{svp}: 1, 1, *if product type p is delivered to opened locker s in van − tour v*; 0, *else*

With the notation stated, the three-stage optimization approach is presented consecutively.

Stage 1: LRP for grocery locker location planning

$$Min = \sum_j \sum_m F_{jm} \cdot o_{jm} + \sum_j \sum_m \sum_\theta \Delta_{\theta m}^{van} \cdot c^{van} \cdot o_{jm} \qquad (1)$$

$$\Delta_{gh}^{ecb} \cdot y_{nm} \leq \alpha \qquad \forall\, n, m \qquad (2)$$

$$\sum_m y_{nm} = 1 \qquad \forall\, n \qquad (3)$$

$$\sum_j o_{jm} \geq y_{nm} \qquad \forall\, n, m \qquad (4)$$

$$\sum_j o_{jm} \leq 1 \qquad \forall\, m \qquad (5)$$

$$\sum_n d_{np} \cdot y_{nm} \leq \sum_j Q_{jp}^{gl} \cdot o_{jm} \qquad \forall\, m, p \qquad (6)$$

$$o_{jm} \in \{0,1\} \qquad \forall\, j, m \qquad (7)$$

$$y_{nm} \in \{0,1\} \qquad \forall\, n, m \qquad (8)$$

The objective function in (1) minimizes the costs of the established grocery locker network and the supply with goods from the depot. Constraint (2) limits the maximum distance between grocery lockers and assigned customers allowing for short travel distances and resulting cooling chain requirements in case of customer self-collection as well as delivery via ECB. The proper assignment of customers to grocery lockers and its required size is secured by constraints (3) to (6). The constraints (7) and (8) define the decision variables' value ranges.

Stage 2: VRP for grocery locker to customer routing

$$Min = \sum_g \sum_h \sum_k \Delta_{gh}^{ecb} \cdot c^{ecb} \cdot x_{ghk} \tag{9}$$

$$\sum_h \sum_k x_{\beta hk} = 1 \qquad \forall\, \beta \tag{10}$$

$$\sum_g x_{hgk} - \sum_g x_{ghk} = 0 \qquad \forall\, h, k \tag{11}$$

$$\sum_\beta \sum_s x_{\beta sk} \leq 1 \qquad \forall\, k \tag{12}$$

$$u_l - u_\beta + |\Omega| \cdot x_{l\beta k} \leq |\Omega| - 1 \qquad \forall\, l \in \Omega, \beta, k \tag{13}$$

$$\sum_\beta \sum_h \sum_p d_{\beta p} \cdot x_{\beta hk} \leq Q^{ecb} \qquad \forall\, k \tag{14}$$

$$\sum_g \sum_h \Delta_{gh}^{ecb} \cdot x_{ghk} \leq \bar{\Delta}^{ecb} \qquad \forall\, k \tag{15}$$

$$\sum_\beta d_{\beta p} \cdot y_{\beta s} + \sum_\eta d_{\eta ps} \leq \sum_j Q_{jp}^{gl} * o_{js} \qquad \forall\, p, s \tag{16}$$

$$\sum_h \left(x_{\beta hk} + x_{shk}\right) - y_{\beta s} \leq 1 \qquad \forall\, \beta, s, k \tag{17}$$

$$\sum_s y_{\beta s} = 1 \qquad \forall\, \beta \tag{18}$$

$$t_{\beta k} \geq T_\beta^{min} \qquad \forall\, \beta, k \tag{19}$$

$$t_{\beta k} + \tau \leq T_\beta^{max} \qquad \forall\, \beta, k \tag{20}$$

$$t_{gk} + \sum_\phi \sum_p d_{\phi p} \cdot x_{g\phi k} \cdot \lambda + \delta_{g\beta}^{ecb} - \left(1 - x_{g\beta k}\right) \cdot \mathcal{M} \leq t_{\beta k} \qquad \forall\, g, \beta, k \tag{21}$$

$$t_{gk} + \tau + \delta_{gh}^{ecb} - \left(1 - x_{ghk}\right) \cdot \mathcal{M} \leq t_{hk} \qquad \forall\, g, h, k; g \neq h \tag{22}$$

$$x_{ghk} \in \{0{,}1\} \qquad \forall\, g, h, k \tag{23}$$

$$y_{\beta s} \in \{0{,}1\} \qquad \forall\, \beta, s \tag{24}$$

The objective function of the second stage (9) minimizes the transport costs for home delivery to customers conducted by ECB. Constraints (10) to (13) assign customers to tours and tours to grocery lockers. The vehicle capacity of each ECB and the tour length is restricted by constraints (14) and (15). Constraints (16) to (18) secure the correct assignment of customers and products to grocery lockers as determined in the first stage. Time window restrictions and tour durations of the ECBs are calculated in constraints (19) to (22). Constraints (23) and (24) define the respective decision variables' value ranges.

Stage 3: VRP for depot to grocery locker routing

$$Min = \sum_a \sum_b \sum_v \Delta_{ab}^{van} \cdot c^{van} \cdot x'_{abv} \tag{25}$$

$$\sum_a x'_{asv} \leq 1 \qquad \forall\, s, v \tag{26}$$

$$\sum_a x'_{asv} - \sum_a x'_{sav} = 0 \qquad \forall\, s, v \tag{27}$$

$$u_{rv} - u_{sv} + |S| \cdot x'_{rsv} \leq |S| - 1 \qquad \forall\, r \in S, s, v \tag{28}$$

$$z_{svp} \leq \sum_a x'_{asv} \qquad \forall\, s, v, p \tag{29}$$

$$\sum_v z_{svp} \leq 1 \qquad \forall\, s, p \tag{30}$$

$$q_{sp} \leq \sum_v z_{svp} \cdot \mathcal{M} \qquad \forall\, s, p \tag{31}$$

$$\sum_s z_{svp} \cdot q_{sp} \leq Q_{vp}^{van} \qquad \forall\, v, p \tag{32}$$

$$\sum_a \sum_b \Delta_{ab}^{van} \cdot x'_{abv} \leq \bar{\Delta}^{van} \qquad \forall\, v \tag{33}$$

$$t_{av} \geq T_a^{min} \qquad \forall\, a, v \tag{34}$$

$$t_{av} + \sum_p q_{ap} \cdot z_{avp} \cdot \lambda \leq T_a^{max} \qquad \forall\, a, v \tag{35}$$

$$t_{\theta v} + \sum_p \sum_\sigma q_{\sigma p} \cdot z_{\sigma v p} \cdot \lambda + \delta_{\theta s}^{van} - (1 - x'_{\theta s v}) \cdot \mathcal{M} \leq t_{sv} \qquad \forall\, s, v \tag{36}$$

$$t_{av} + \sum_p q_{ap} \cdot z_{avp} * \lambda + \delta_{ab}^{van} - (1 - x'_{abv}) \cdot \mathcal{M} \leq t_{bv} \qquad \forall\, a, b, v; a \neq b \tag{37}$$

$$x'_{abv} \in \{0,1\} \qquad \forall\, a, b, v \tag{38}$$

$$z_{svp} \in \{0,1\} \qquad \forall\, s, v, p \tag{39}$$

The third stage objective function (25) minimizes the transport costs for the supply of the established grocery lockers. Lockers have to be visited by vans and the correct tour flow is ensured by constraints (26) to (28). Constraints (29) to (31) guarantee the delivery of products to grocery lockers, while split deliveries are possible. Thresholds regarding van and compartment capacities as well as the tour length are restricted in constraints (32) and (33). Constraints (34) to (37) secure the grocery locker related time window observance. Constraints (38) and (39) define the decision variables' value ranges.

9.3. Application Example and Discussion of Results

To evaluate our developed multi-echelon optimization approach for an exemplary day, benchmark calculations based on the city of Hannover (Germany) are provided. Figure 36 illustrates the investigation area consisting of 25 potential grocery locker locations (triangles), 100 customer locations (dots), and a depot that is placed approximately 26 km outside the city. The benchmarks are calculated by application of the presented multi-echelon optimization model with the modeling software *GAMS 24.5.6* using the solver *IBM ILOG CPLEX 12.6.1*. With a standard computer (Intel Core i5-6200U, 2.30 GHz, 8 GB RAM), different computing times per stage result. For the first model stage (LRP), most instances are solved with a relative gap of 0%. The calculation of the second and third stage were stopped after an hour with relative gaps of at least 22 respectively 36%.

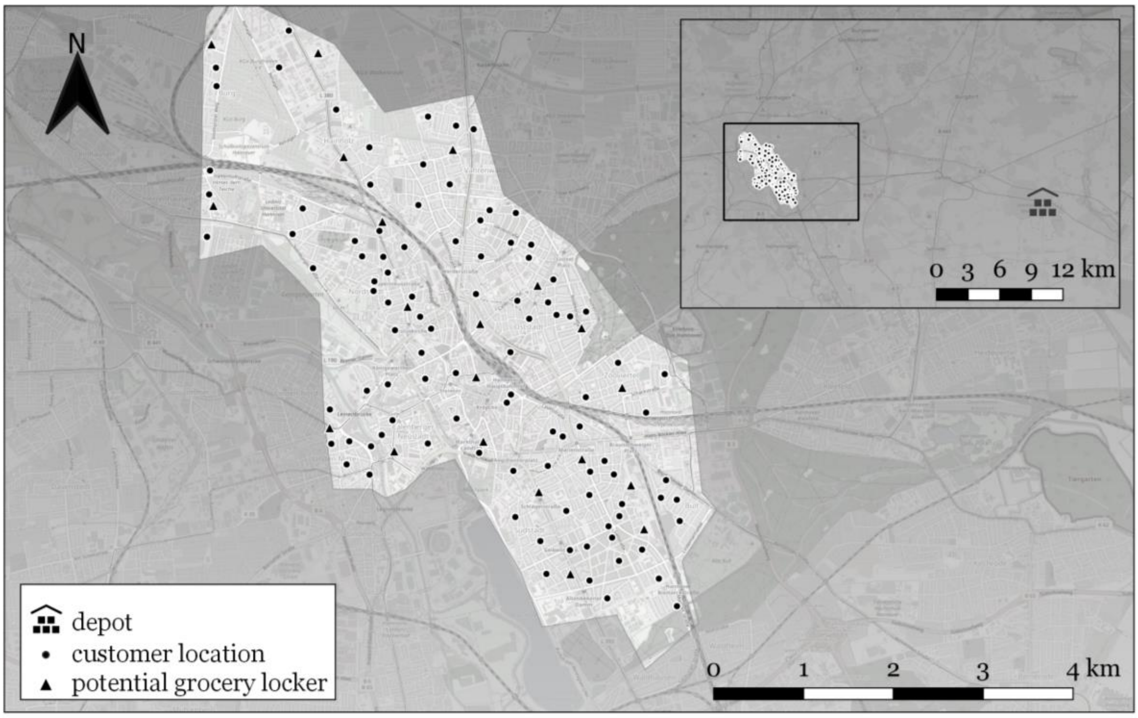


Figure 36. Investigation Area Including Relevant Locations; Based on Leyerer et al. (2020).

Each customer demands a distinct level of three different product types (frozen, refrigerated, and dry). The maximum distance between a customer and its assigned grocery locker is set to 1.25 km, with three possible locker sizes are selectable. The following tables present the benchmarks with their effects on network structure (number of grocery lockers), distance covered (for customer and locker supply), and resulting costs for locker establishment and routes on a daily basis. Table 10 illustrates the results for a varying share of home delivery and self-collection customers.

Table 10. Results for Home Delivery and Self-Collection Ratios; Based on Leyerer et al. (2020).

Home del. / Self-coll. [%]	**Number of grocery lockers**				**Distance**		**Costs**			
	small [#]	medium [#]	large [#]	∑ [#]	ECB [km]	vans [km]	locker [€]	ECB route [€]	van route [€]	∑ [€]
100/0	4	4	0	8	111.82	212.65	116.00	11.18	63.79	190.98
75/25	4	4	0	8	64.36	212.65	116.00	6.44	63.79	186.23
50/50	4	4	0	8	38.81	212.65	116.00	3.88	63.79	183.68
25/75	4	4	0	8	18.55	212.65	116.00	1.85	63.79	181.65
0/100	4	4	0	8	0.00	212.65	116.00	0.00	63.79	179.79

Evidently, a higher share of home delivery customers result in an increasing number of transports for the grocer. With a higher proportion of self-collectors, this amount is reduced as the customers cover the last mile by themselves and less grocer deliveries are required. As a result, with a share of 100% self-collection customers, no ECB tours are conducted. With a rising share of home delivery customers, ECB grocer mileage increases steadily. However, the resulting effect on cost is marginal. Irrespective of the decision, whether the goods are delivered or not, identical capacities of storable goods incur. Accordingly, the routes to supply the grocery lockers are also identical and remain unchanged in costs. In conclusion, total costs rise from 179.79 €/day to 190.98 €/day by only 6.22% if all customers demand home delivery.

Further investigated are variations in terms of the maximum permitted distance between customers and the assigned grocery lockers. With a share of 50% home deliveries and equally 50% customer self collection, the obtained results are displayed in Table 11. With a lower distance, the number of established grocery lockers, the number of ECB tours, and overall costs increase; for a value of 0.5 km, the total costs amounts to 320.10 €/day with 25 opened lockers and resulting locker costs of 250.00 €/day. From an economic point of view, the number of opened grocery lockers must be minimized. On the other hand, the ECB distance is reduced when more lockers are established as shorter routes minimize the urban LMD. When increasing the distance, less grocery lockers are deployed as more customers can be served per locker. In addition, for capacity reasons the small lockers will be replaced by medium or large ones. In case of a maximum distance of 2.0 km, the lockers are placed at centralized locations within the investigation area.

Table 11. Results for Different Distances from Lockers to Customers; Based on Leyerer et al. (2020).

Max. dist. [km]	**Number of grocery lockers**				**Distance**		**Costs**			
	small [#]	medium [#]	large [#]	∑ [#]	ECB [km]	vans [km]	locker [€]	ECB route [€]	van route [€]	∑ [€]
0.50	25	0	0	25	24.30	225.56	250.00	2.43	67.67	320.10
0.75	19	0	0	19	32.55	223.87	190.00	3.26	67.17	260.42
1.25	4	4	0	8	38.81	212.65	116.00	3.88	63.79	183.68
1.75	2	0	3	5	43.82	209.89	101.00	4.38	62.97	168.35
2.00	0	1	3	4	50.95	202.32	100.00	5.09	60.70	165.79

To compare the conducted benchmark calculations on different network structures of the proposed logistics concept with conventional e-grocery delivery, the following Table 12 shows the results in terms of economic and environmental effects. Besides the number of grocery lockers, required travel distances, and resulting costs, the environmental effects are reflected by urban space requirements and locally produced emissions. In this regard, a value of 192 gCO_2 per driven van kilometer is assumed. In case of a conventional delivery, vans deliver demanded products directly from the depot to the customers' homes. To ensure the comparability of the results regarding both delivery concepts, the third stage of the presented multi-echelon model is used. The mathematical model is thereby reduced by the possibility of split-delivery, as customers are supposed to receive all products in a single delivery within their corresponding individual time-window(s). The input parameters and other constraints of the model remain identical.

Table 12. Comparison of E-Grocery Delivery Concepts; Based on Leyerer et al. (2020).

Scenario		**Conventional delivery of groceries**	**New logistics concept** [100% home delivery; 0% self-collection; max. distance 1.25 km]	**New logistics concept** [50% home delivery; 50% self-collection; max. distance 2.0 km]
Number of lockers	Small [#]	0	4	0
	Medium [#]	0	4	1
	Large [#]	0	0	3
	∑ [#]	0	8	4
Travel distance	ECB [km]	0	111.82	50.95
	Vans [km]	293.27	212.65	202.32
Local emissions [$kgCO_2$]		56.31	40.83	38.85
Space requirement [m^2]		0	48	44
Costs [€/day]		87.97	190.98	165.79

In case of a conventional home delivery, the 100 home delivery customers are supplied by vans with a total travel distance of 293.27 km. This amounts to 56.31 kgCO_2 per day, with/and no space requirements for lockers. In total, costs of 87.97 € incur. The proposed logistics concept with a setting of 100% home delivery, 0% self-collection, and a maximum distance between lockers and customers of 1.25 km, causes a costs increase of 103.01 € (+117.1%) compared to conventional delivery. Additionally, 48 m^2 urban space are required for the installation of grocery lockers. Van distances are reduced by 80.62 km (-27.5%), which lead to 15.48 kgCO_2 emission savings. With a setting of 50% home delivery, 50% self-collection, and a maximum distance between lockers and customers of 2.0 km, additional costs of 77.82 € (+88.5%) result compared to a conventional delivery. One medium sand three large sized grocery lockers require 44 m^2 more urban space, while van distances are reduced by 90.95 km (-31.0%). Emissions are decreased accordingly.

The presented logistics concept promotes the establishment of a network consisting of grocery lockers. With grocery lockers positioned at favorable locations, road traffic can be reduced irrespective of self-collection and home delivery shares. Compared to a conventional delivery of e-groceries, the proposed logistics concept requires more space, while van kilometers and emissions are reduced. When customers pick up their products by themselves via bicycle or by foot, this effect increases even more. Integrating a maximum distance between a grocery locker and its assigned customers directly influences grocery locker network density. The lower the parameter value, the closer the grocery locker to its assigned customers, which is crucial for the acceptance of customers in terms of self-collection (Iwan et al., 2016). With different ratios of home delivery and self-collection customers, the grocer's mileage and costs decrease with a rising share of self-collection. Short distances encourage customers to collect their products by themselves and promote the use of ECB in case of delivery. City authorities can support this logistics concept by setting up special purpose areas to promote the use of pickup points. For the supply of grocery lockers by vans, the depot location heavily influences the results.

9.4. Contributions, Limitations, and Future Research

The proposed e-grocery logistics concept contributes to enhanced environmental sustainability by reducing the negative externalities of last mile deliveries. By application of the concept, urban road traffic is relieved and vehicle emission decreased. Further, the social dimension of sustainability is addressed as the potential set of employees is extended because no driving license is required. The impact of self-collections of customers can increase the people's awareness for eco-friendly goods transportation. With the proposed mathematical model, decision making is enabled for (e-)grocery retailers and parcel delivery services to find appropriate solutions for the sustainable distribution of e-groceries in urban areas. As additional costs occur for this concept, city authorities are supported in understanding the implications for providers and in deriving appropriate measures.

The proposed concept itself has to be considered as its current main limitation. At present, a concept consisting of an urban network of refrigerated grocery lockers has not been implemented on a large scale. It is therefore not possible to properly evaluate its usefulness or its customer acceptance. Additionally, regarding the mathematical model, there are limitations and enhancement opportunities to be mentioned as it is based on several assumptions to simplify real-world conditions. Due to of the high amount of decision variables and constraints, a multi-echelon optimization approach is chosen. In doing so, the planning process is divided into three sub-problems reducing the complexity of the model. As LRP and VRP are NP-hard combinatorial optimization problems, comparatively long computing times result (Prodhon and Prins 2014). For practical implementation, the optimization has to take place within a few hours maximum. The handling of moderate problem instances for medium-sized cities, as presented within the benchmark section, is feasible with the developed approach. With rising e-grocery shares on-hand, the models solution efficiency is not secured. For a solution of large instances, computing times have to be reduced. To obtain quicker decision support, a (meta-) heuristic solution procedure has to be developed for the introduced e-grocery delivery concept. In this context, the assumption of temporary grocery locker relocation should be examined, as daily change in location may not represent the most suitable long term approach.

Future research must focus on a refinement of the underlying mathematical models and on the development of a suitable heuristic framework in the discussed ways. A field test of the proposed logistics concept to ensure further validation is recommended. Also, the customer acceptance of e-grocery delivery and the self-collection of ordered goods have to be investigated. In general, an industry expert must assess the applied parameter values in the computational study, especially the cost factors. If the approach proves to be advantageous compared to present business practices, it should be fine-tuned and applied on large scale.

10. Customer Acceptance of Delivery Concepts

10.1. Academic Classification

The article "Customer Acceptance of Urban Logistics Delivery Concepts" is topic of investigation in section 10 (Sonneberg et al. 2019c and Appendix O). The article was a collaboration of Marc-Oliver Sonneberg, Oliver Werth, Human Kohzadi, Marvin Kraft, Bjarne Neels, and Michael H. Breitner: The study was published in the unrated IWI Discussion Paper Series and was not subject to a typical peer review. The article is part of the project *USEfUL* (grant number: 03SF0547B) and was funded by the *German Federal Ministry of Education and Research* (BMBF). *The following section 10 is largely based on Sonneberg et al. (2019c).*

10.2. Problem Description and Approach

The objective of the article is to examine potential acceptance factors for urban logistics concepts from an end customer perspective. The number of shipments in cities has continuously increased in recent years due to urbanization and rising individual needs, especially through the effects of growing online retailing. The resulting challenge of ascending parcels to be delivered for (urban) logistics providers demand for the creation and implementation of new logistics concepts. The efficient and flexible supply of shipment options is the main focus, whereby these options have to be compatible with the needs of the inhabitants and the environment. With regard to alternative delivery methods, a successful implementation primarily depends on the acceptance and application of end customers (Wang et al., 2018).

Regarding scientific research, publications on customer acceptance of urban logistics concepts are limited. Niehaus (2005) investigates various box-alike delivery systems for home deliveries that are not equipped with IT. Ehrler and Hebes (2012) conducted a study on the use of electro mobility in urban areas to elaborate user needs, expectations, and acceptance by vehicle drivers, buyers, and end customers. De Oliveira et al. (2017) analyze the online shoppers' attitudes towards an automatic delivery station compared with traditional home delivery. Wang et al. (2018) focus on the examination of the customers' acceptance for the use of an automated parcel station. To address this research gap, several logistics concepts are analyzed regarding customer acceptance for parcel and e-grocery deliveries in urban areas. These logistics concepts are briefly described in Table 13.

Table 13. Overview of Investigated Concepts; Based on Sonneberg et al. (2019c).

1	*BentoBox*: steel housing accommodating small mobile containers of various formats and an user terminal
2	*Parcel Station with Delivery Service*: cross-supplier consignation and storage of parcels with customer selection of individual delivery times
3	*In-Car Parcel Delivery*: parcel are delivered in the trunk of a personal vehicle instead of traditional home delivery
4	*Parcel Drone Delivery*: parcel are delivered immediately via drones to customers landing spots instead of traditional home delivery
5	Parcel Robot Delivery: parcel are delivered via delivery robot to customers' homes not requiring delivery men
6	*Parcelbox*: large mailbox for parcels that can be installed in front of houses or at apartment doors
7	*Concierge Service at Workplaces*: parcels are delivered to workplaces of recipients instead of traditional home delivery
8	*White-Label CEP Service*: neutral delivery service that handles distribution over the last mile across all delivery companies
9	*Unattended In-Home Delivery*: parcel are traditionally delivered to customers' homes, with delivery men being granted short-term access to the housing unit
10	*Neighborhood Supply of Groceries*: process in which neighborhoods jointly organize their food procurement through effective division of labor
11	*Click & Deliver of Groceries (Multichannel)*: in a virtual supermarket customers order groceries, which are delivered by the grocer's own fleet
12	*Click & Deliver of Groceries (Online Pure Player)*: in a virtual supermarket customers order groceries, which are delivered by the traditional CEP services
13	*Click & Collect of Groceries*: in a virtual supermarket customers order groceries, which are self-collected by the customers at a desired grocer store
14	*Grocery Pick-Up Station*: in a virtual supermarket customers order groceries, which are self-collected by the customers at transfer points of public transport

For all of these concepts, the corresponding acceptance was investigated by applying the theoretical framework of UTAUT2. Therefore, our guiding research question was:

Which factors influence the acceptance of urban logistics concepts among end customers?

To answer this research question, the hypotheses depicted in Table 14 are developed. As 14 different logistics concepts are part of investigation in terms of their acceptance and their intended usage, the research model is separately employed for each concept resulting in an analyses of 14 individual models. With identical constructs and corresponding relations, the hypotheses for each concept are phrased identically. Therefore, the hypotheses are only presented by an example for a single concept, namely the first concept of BentoBox.

Table 14. Overview of Hypotheses for Concept 1: BentoBox; Based on Sonneberg et al. (2019c).

H01.1	The PE of the BentoBox has a positive influence on the BI to use the BentoBox.
H02.1	The EE of the BentoBox has a positive influence on the BI to use the BentoBox.
H03.1	The SN regarding the BentoBox has a positive influence on the BI to use the BentoBox.
H04.1	The FC regarding the BentoBox have a positive influence on the BI to use the BentoBox.
H05.1	The FC regarding the BentoBox have a positive influence on the UB.
H06.1	The HM regarding the BentoBox has a positive influence on the BI to use the BentoBox.
H07.1	The PV of the BentoBox has a positive influence on the BI to use the BentoBox.
H08.1	The HT regarding the BentoBox has a positive influence on the BI to use the BentoBox.
H09.1	The HT regarding the BentoBox has a positive influence on the UB.
H10.1	The SE of the BentoBox has a positive influence on the BI to use the BentoBox.
H11.1	The BI to use the BentoBox has a positive influence on the UB.

The methodological focus is based on quantitative data collection by means of the online software *surveymonkey*. The questionnaire was distributed across social networks and the email list of our transportation research network. Relevant data was collected in the second half of 2018. After general information on the scientific purpose, the anonymity, and the procedure of the survey presented, respondents provide basic information about themselves including gender, age, professional situation, the place of residence, and their average personal parcel reception per month. Subsequently, the participants were automatically assigned to one of the 14 concepts by random selection. The concepts were briefly described and illustrated using a concept description, a presentation video, or both. All questions of the items and corresponding constructs are measured using a seven-step Likert scale with a range from “strongly disagree” (1) to “strongly agree” (7). Out of 807 participants, the survey was completed by 494 respondents resulting in a dropout rate of 39%.

Using *SmartPLS* (v. 3.2.8) for measurement validation and model testing, the default settings were adapted from the recommendations of Hair et al. (2012). Indicator reliability, composite reliability, average variance extracted, and discriminant validity were tested in terms of model measurement assessment with none to only few items dropped per concept. For significance testing, the bootstrapping method was chosen with 500 subsamples.

10.3. Presentation and Discussion of Results

Within the study, 154 hypotheses for the acceptance analysis of end customers with regard to 14 different urban logistics concepts were conducted. Testing the hypotheses determines, which of the hypotheses are supported on the basis of relevant path coefficients and further relevant measures not mentioned here. To accept the developed hypotheses, the path coefficient has to correspond to the presumed positive influence and has to be statistically significant. If at least one of the conditions is not fulfilled, the hypothesis has to be rejected. Table 15 illustrates the results of the hypotheses testing. If a hypothesis is accepted, the corresponding path coefficient as impact is stated together with the significance level.

Table 15. Overview of Accepted Hypotheses and Path Coefficient; Based on Sonneberg et al. (2019c).

Note: *p<0.1; **p<0.01; ***p<0.001

		1	**2**	**3**	**4**	**5**	**6**	**7**
H01.x	PE→BI		0.398**	0.330*	0.432**	0.423***		
H02.x	EE→BI					0.254*		
H03.x	SI→BI			0.368**	0.303*			
H04.x	FC→BI							
H05.x	FC→UB						0.351*	
H06.x	HM→BI						0.655***	0.598***
H07.x	PV→BI							
H08.x	HT→BI		0.372**					
H09.x	HT→UB	0.623***		0.522***	0.545***	0.556***	0.453***	0.688***
H10.x	SE→BI							0.250*
H11.x	BI→UB		0.395*					
		8	**9**	**10**	**11**	**12**	**13**	**14**
H01.x	PE→BI				0.331*		0.416***	0.441*
H02.x	EE→BI							
H03.x	SI→BI		0.408**		0.312**		0.352**	
H04.x	FC→BI							
H05.x	FC→UB							
H06.x	HM→BI			0.595**				
H07.x	PV→BI				0.532**			0.213*
H08.x	HT→BI							
H09.x	HT→UB	0.430**	0.513***	0.671***	0.578***	0.389*	0.520***	0.521***
H10.x	SE→BI	0.242*					0.286*	0.367***
H11.x	BI→UB		0.293*				0.307*	

As visible in Table 15, only 40 out of 154 hypotheses were supported, which means the identified positive influences were significant on a distinct level. The constructs with rejected hypotheses have no influence on the UB or the BI to use investigated concepts. These results answer our research question as follows: only the PE and SI has significant influence on the BI to use a concept as well as the HT that positively influences the UB of a concept. Other constructs are only relevant for less than five concepts, which is why these are disregarded in further analysis. The constructs of PE, SI, and HT are discussed in the following and brief recommendations of action for providers are drawn.

PE has a positive influence on the BI for seven of the investigated urban logistics concepts (Parcel Station with Delivery Service, In-Car Parcel Delivery, Parcel Drone Delivery, Parcel Robot Delivery, Click & Deliver of Groceries (Multichannel), Click & Collect of Groceries, and Grocery Pick-Up Station). This leads to the conclusion that end customers believe using the addressed concepts help them to improve their performance. Above all, time savings and related productivity improvements are achieved by these concepts. This is due to the possibility of individually selectable delivery or pick-up times, which allows for more flexibility in a time saving parcel reception. However, this was not the case for other concepts, some of which suggest similar relationships. Based on the results, CEP service providers and grocers should focus on as requested by the customer as well as the provision of real-time tracking opportunities. Otherwise, negative customer satisfaction, increased time expenditure, and reduced productivity on the customers' side can result.

The construct SI has significant influences on BI for five concepts, namely In-Car Parcel Delivery, Parcel Drone Delivery, Unattended In-Home Delivery, Click & Deliver of Groceries (Multichannel), and Click & Collect of Groceries. Important persons of the respondents, e.g. family member or close friends, consider the usage of these five concepts useful, which results in a substantial influence. For the mentioned CEP service concepts, this can be due to the innovation of the one side and privacy concerns on the other side. For the grocery concepts, it can be interpreted that customers adopt Click & Deliver (Multichannel) and Click & Collect if important persons have a positive opinion about using these e-food delivery concepts. If not, the respondents are restricted in their acceptance. As other concepts do not have a significant impact regarding the SI on the BI, CEP service as well as e-grocery providers should examine to what extent they can have a positive influence on the social environment of customers. Advertising measures, publication of positive customer feedback, or promotional videos of the concept could highlight the advantages of the concepts mentioned.

HT is observed as the most important factor influencing actual UB showing a positive influence for 13 concepts (except for Parcel Station with Delivery). Regarding the concepts, the greater the HT of the customers, the greater the likelihood of actual use. If a certain level of HT is existent, the UB will automatically increase. Short trials of delivery concepts are definitely not the key for customer acceptance. To obtain HT, logistics service providers or public authorities could set incentives. Further, public authorities have to set regulations, e.g. pollutant restrictions or parking bans, to allow for more eco-friendly logistics concepts. As a result, CEP services have to reconsider their approach of parcel delivery and focus more on the implementation and optimization of innovative logistics concepts. Resulting environmental advantages must be demonstrated to the customer. Thus, customers become more familiar with the use of these concepts and eventually developing a stronger HT.

10.4. Contributions, Limitations, and Future Research

The present study expands the current state of research regarding the customer acceptance of urban logistics concepts. Concerning the empirical approach of this study, the research model of UTAUT2 was applied and tested on 14 urban logistics concepts. Thereby, the model was extended by the additional construct SE. As a result, PE, HT, and SI have a major influence for the acceptance and adoption of urban logistics concepts.

In terms of limitations, the survey sample is focused on a German context and is not representative. The characteristics of the respondents were largely homogenous (young academics between 25 and 29 years of age as well as employees younger than 40 years). The sample did not reflect the population in reality why the sample is biased. Despite the number of 494 analyzed respondents' datasets, there are only about 35 participants per concept on average. Even though PLS-SEM methods are suitable for small sample sizes and the model results revealed high predictive accuracy, it is questionable if present sample sizes have been too small to find effect relationships that reflect reality. As only 40 out of 154 hypotheses could be supported, it can be assumed that other factors influence the behavioral intention of customers when ordering goods and grocery online. Concepts to be investigated are, for instance, individual innovativeness, perceived trust, or perceived privacy, which are validated constructs in other acceptance models. Another limitation are the urban logistics concepts itself, as most of them are still in the testing phase. Correspondingly, the answers of the respondents are limited in their meaningfulness, especially with regard to the frequency of use. Since UTAUT2 is used to investigate general technology acceptance, further studies need to verify the suitability of this research model for measuring the acceptance of urban logistics concepts by end customers.

OVERALL DISCUSSION ON URBAN TRANSPORT

<table>
<tr><td colspan="10">Physical Transport</td></tr>
<tr><td colspan="5">Passenger Transport</td><td colspan="5">Freight Transport</td></tr>
<tr><td colspan="2" rowspan="2">Private Passenger Transport</td><td colspan="6">Commercial Transport</td><td colspan="2" rowspan="2">Private Freight Transport</td></tr>
<tr><td colspan="2">Commercial Passenger Transport</td><td colspan="2">Commercial Service Transport</td><td colspan="2">Commercial Freight Transport</td></tr>
<tr><td colspan="4">Urban Mobility</td><td colspan="6">Urban Logistics</td></tr>
<tr><td colspan="10">Urban Transport</td></tr>
</table>

Figure 37. Classification of Transport Modes: Urban Transport; Adapted from Arndt (2010).

Increasing economic, ecological and social aspirations of citizens worldwide, changing consumption and production patterns, and limited natural resources are driving innovation in the transport sector. Transport services and infrastructure are no longer seen as simple means of moving people and goods from A to B – but mobility and logistics are increasingly perceived as key agents of change.

Eekhoff et al. (2015:4)

"Efficient and effective urban transport can significantly contribute to achieving objectives in a wide range of policy."

European Commission (2019:1)

A Primer to the Overall Discussion on Urban Transport

The general aim of this cumulative dissertation and the related research articles is to support decision making by provision of recommendations for organizational stakeholders in solving present problems or improving the current situation (Todd and Benbasat, 1992). This applies to both the developed optimization models and related DSS as well as the conducted quantitative surveys.

In the previous sections of part A and B, important articles of the dissertation were presented. With the intention to provide a comprehensible summary, sections 2 to 10 focus on essential core elements of the respective articles. Further details can be found in the corresponding articles (see appendices). The motivation, the positioning regarding the research topic as well as a brief literature overview on the topic, and the applied research methodology were introduced in the primers to urban mobility and urban logistics. In each of the sections in part A (sections 2 to 5) and part B (sections 6 to 10), problem descriptions, approaches, and corresponding results were presented. Additionally, a critical assessment including contributions, limitations, as well as future research was carried out for each section individually.

The subsequent section 11 concentrates on the overall classification and critical assessment of all urban transport related research articles of this dissertation collectively as well as the applied IS methods. Subsection 11.1 reviews the superordinate contributions of the research articles as well as the associated scientific work as research assistant. Initially, the focus is on the overall research topic of the dissertation, urban transport. Subsequently, contributions related to the applied methodologies of design science and behavioral science are elaborated. In subsection 11.2, related overall limitations regarding the thematic focus and applied research methods are presented. Finally, subsection 11.3 provides an outlook with regard to future developments in urban transport and corresponding suggestions for further research for passenger, goods, and service transports.

11. Contributions, Limitations, and Outlook

11.1. Discussion of Contributions

Contributions to Urban Transport

Within the scope of this cumulative dissertation, a general attention to current and future challenges in the field of urban transport was drawn. This was accomplished by publishing conducted approaches and their results in outlets of the research areas IS, OR, transport, and logistics. By means of presentations at public events, academic teaching, and the supervision of theses, an awareness for urban transport problems was raised. A further contribution during my time as research assistant was the task of review activities. These reviews were conducted in the IS, OR, transportion, and logistics community for journals (e.g., Journal of Management Information Systems, Decision Support Systems, Transportation Research Part E) as well as for conference articles (e.g., ICIS, WI, HICSS). Moreover, I significantly contributed to the development and progress of the BMBF-funded research project *USEfUL* (grant number: 03SF0547B). Within this project, city authorities are supported in finding solutions for urban logistics processes by conducting scenario analyses with the aid of traffic simulation tools. The developed methods, models, and their results were regularly presented and improved based on discussion with relevant stakeholders from industry, science, and city authorities in the surrounding *Initiative Urbane Logistik Hannover*.

Besides these stakeholders, city dwellers must realize that they are the trigger for the increase in road traffic and its consequences in terms of congestion and pollution. Due to increasing urbanization and the growing demand for mobility and transportation, awareness must be raised to the entire population regarding the urgency of sustainable LMD of passengers, goods, and services. With the intention of mitigating the described problems, several concepts were presented within the research articles as possible partial solutions. These enable an efficient use of existing resources (e.g., road and parking space) and thus allow for a more sustainable way of life. Besides emphasizing economic and environmental sustainability, also the social dimension was addressed in terms of feasibility for all inhabitants to participate. With a focus on sustainability, organizational decision makers apply the presented approaches to be supported in finding appropriate results. Practical implications and recommendations for action derived within the articles permit the derivation of generalizations.

Contributions to Design Science Research

The majority of research articles in this dissertation are based on a DSR methodology according to Hevner et al. (2004). The iteratively developed artifacts in the design cycle constitute of mathematical optimization models, which are partly also incorporated within a DSS. These artifacts were formulated based on identified research gaps in the rigor cycle. Consequently, the created artifacts extend the literature base, while providing decision support for relevant decision makers. Especially in case of a developed DSS, the adjustment of parameters within an intuitive GUI does not require optimization knowledge by decision makers. With the presented artifacts, it is possible to give recommendations for action for the investigated concepts. To support providers even without the optimization of own scenarios, critical parameters are revealed and related generalizations are highlighted. These generalizations include the demand as well as restrictions regarding the service level (e.g., maximum distance between customer and supply location, CO_2-emission limits), which are decisive for profit and loss.

Besides the aforementioned contributions of developed artifacts, the articles of this dissertation contribute to the Green IS literature, as important issues of the transition to a more sustainable urban transport are addressed. The underlying research approaches constitute a reaction to the calls of Gholami et al. (2016), Malhotra et al. (2014), and Seidel et al. (2017), who point out the overrepresentation of conceptualizations and analyses compared to solution-oriented research. Transportation, logistics, OR, and (green) IS research is combined to promote the transformative role of IS in contributing to enhanced economic, social, and environmental sustainability. In DSR, artifacts are differentiated between instantiations, constructs, models, methods, and design theories (March and Smith, 1995; Gregor and Hevner, 2013). As the developed artifacts of this dissertation represent mathematical models and (partly) DSS, these can be classified as models and instantiations. Following the knowledge framework of Gregor and Hevner (2013), the artifacts are described as nascent design theories and can be seen as the higher-level contributions to IS, DSS, and DSR research.

Contributions to Behavioral Science

Besides the optimization of urban transport concepts, quantitative surveys were conducted by applying behavioristic research approaches. While examining scientific literature, research gaps in the fields of ridepooling and alternative urban logistics concepts were identified. In the case of ridepooling, no acceptance study could be identified, while in the area of urban parcel delivery, only parcel station concepts were examined more closely in terms of acceptance.

In order to address these research gaps, well-founded scientific acceptance methods were used and adapted to the respective topic. In addition, these were extended by additional constructs and items, resulting in both practical and theoretical contributions. With the help of structural equation modeling according to the PLS-SEM procedure, crucial factors of potential customers were identified for the investigated transport concepts and solutions. Based on the gathered insights, providers of such transport services are supported with useful recommendations for action, which, based on the obtained findings, lead to higher customer acceptance, a greater intention to use, and an increased profit for ridepooling providers.

11.2. Discussion of Limitations

Limitations regarding Urban Transport

Besides specific limitations of the individual thematic sections that are presented and discussed in the corresponding research articles, this section compiles overall limitations regarding the introduced articles and investigated research topics of urban mobility, urban logistics, and urban transport. As a general remark, it is worth mentioning that even though most research articles were evaluated during peer-review processes and the quality of publications can consequently be assumed as high (Bortz and Döring, 2006), there are still limitations to each of the approaches as well as to the overall dissertation.

With all due diligence, it must be noted that the research focus on urban mobility was substantiated with only two urban mobility concepts for passenger transport. Objects of investigation were station-based carsharing and ridepooling, which are part of the NMS. NMS try to reduce physical and immaterial inefficiencies by applying the concept of sharing. Up-to-date, most urban passenger trips are covered by private vehicles or public transport, which were not part of the investigations within this dissertation. Yet, these transport modes are predominantly used for regular transport purposes, for example, commuting trips (Statista, 2019a). Currently, those trip purposes cannot be reasonably conducted by carsharing or ridepooling as higher costs occur. However, for irregular journeys, price awareness is usually not the decisive factor (König et al., 2018). Especially for city dwellers, who do not own a vehicle, carsharing or ridepooling represents a suitable option for occasional trips that cannot be efficiently covered by public transport. To conclude, it is doubtful if the NMS' credo of offering sharing services results in an actual abolition of private vehicles, which strongly depends on whether these services eventually become attractive for regular trips, for instance by means of improved offers for daily commuters.

Besides user numbers (*MOIA* in Hamburg and *BerlKönig* in Berlin have approximately 250,000 registered customers each), reliable operational information on ridepooling services and its user patterns is not available. In contrast, 1.08 million Germans have been active carsharing users in 2019 (Statista, 2019b; Statista, 2019c). Station-based carsharing concepts are available in 740 German cities with approximately 650,000 registered customers. By contrast, free-floating concepts without stations are operated in 18 major German cities, whereby these services attract about 1.8 million registered customers (not necessarily active users). Station-based carsharing is no longer newly established in large cities, yet it is becoming increasingly important in small cities and towns. In contrast to large cities, free-floating in small ones would lead to an imbalanced vehicle distribution due to the centralized city structure and its low supply of public transport. These incurring vehicle relocations are less frequent in large cities, as the demand is higher and more diversified based on a polycentric city structure. However, if examining NMS as a whole, forecasts indicate a significant increase in the number of associated vehicles sold. According to Statista (2019c), by 2025 approximately 10% of all vehicles sold will be procured for NMS in the USA, 15% in the EU, and 35% in China. Even with these forecasts at hand, it must be remarked that NMS will not be able to fully satisfy the growing mobility needs of people in (large) cities. The discussed concepts of carsharing and ridepooling accommodate only a few number of passengers on board, which can essentially be described as an inefficient use. Therefore, the NMS are to be perceived as complementary options to existing public transport networks used for passengers' first as well as last mile purposes. A transition from the use of private vehicles, accounting for the largest share of urban transport, to the analyzed concepts is illusory to occur without regulatory intervention by city authorities.

The topics of urban logistics dealt with in this dissertation mainly concentrate on CEP and e-grocery services. In relation to today's entire urban transport system, which is still highly focused on private vehicles (86.5%), both elements together constitute only a small subset of about 1% of urban transport purposes (Kummer et al., 2019). Despite this comparatively low share of vehicles, they depict a notable issue regarding urban traffic, due to congestion, reduced parking space, and even safety critical aspects such as blocked ambulance or fire brigade access. In addition to the number of stops, the duration of stops is described a suitable indicator of the impact on road and parking space. In urban areas, the number of stops by suppliers is almost three times higher than those stops caused by CEP service providers; slightly higher values persist for the taxi and craftsmen sectors (Schäfer et al., 2019). Considering the parking duration, CEP services require many short-term stops, while other mentioned industries tend to occupy parking space for longer periods. However, detailed information on operational characteristics and data in this regard are still missing. This issue was also faced by the logistics project *USEfUL*. Due to missing reliable knowledge of the specific requirements in the areas of goods and service delivery, only one of the articles presented in this dissertation (Leyerer et al., 2019a, see Appendix P) could offer added value in terms of customizable routing for commercial transporters irrespective of delivered goods and services.

Since the CEP market is expected to record a further increase in shipment volumes, the share of commercial traffic will continue to grow. The logistics concepts described and optimized in this dissertation cannot solve this problem. In this context, Van Audenhove et al. (2015) described four different areas of action when aiming to reduce externalities of urban logistics processes. Besides adding infrastructure elements to the supply chain and applying more efficient technologies (both part of investigation within this dissertation), regulations and incentives are key factors to be considered. Nevertheless, it is necessary to incorporate these areas of action in pilot projects to capture the effects and thus validate the insights gained through theoretical approaches. This way, it will be possible to combine and compare different control options on urban logistics. Besides the introduction of new elements (micro-hubs or self-collection points) to the urban LMD, there are other elements to be investigated. One such example is a cross-company cooperative CEP delivery that is also referred to as white label logistics. However, this kind of delivery pattern, in which competing companies cooperate, can only be realized by implementation of regulations through city authorities.

When analyzing the development of e-grocery deliveries, the German market size is expected to double by 2022 according to IGD (2018). With a share of currently 0.5% of the total turnover of this industry, the impact on transport is rather small. In a worldwide comparison, countries such as France, Great Britain, USA, China, or South Korea record significantly higher sales in the e-grocery sector. In contrast to Germany, these countries do not dispose a dense supermarket network within urban centers, but large stores located in the periphery of the cities. Based on the present acceptance and demand, the concept of e-grocery in Germany is still in its infancy and time has to proof if the forecasted figures will eventually result.

To conclude, this dissertation investigates only a limited selection of transport concepts for passengers, goods, and services. The continuing increase in demand from city dwellers and resulting LMD will cause an increasing pressure on existing infrastructures in the next years. Presented approaches do not claim to constitute a comprehensive solution, but rather a starting point to support this change process. In addition, derived statements and generalizations must be scientifically as well as practically verified. By applying developed mathematical models, DSS, or acceptance analyses to other investigation areas, potentially divergent results may be obtained leading to different recommendations for action. A further limitation is the circumstance that a direct combination of quantitative and qualitative research methods with corresponding mutual influence measures was not carried out. These so-called mixed methods approaches would help to gain further or more detailed insights into the investigated real-world transportation problems (Venkatesh et al., 2013).

Limitations regarding Design Science Research

The first limitation regarding the applied DSR methodology is the general justification of relevance and rigor. In IS research, there is an ongoing debate on both elements, which are fundamental for the development process of artifacts (Benbasat and Zmud, 1999; Desouza et al., 2006; Straub and Ang, 2011).

Within DSR approaches, no quality criterion exists to classify a topic as relevant or as a topic that requires research on appropriate solutions. Therefore, relevance is mostly based on subjective measures, which ideally can be supported by objective statements that describe the topic as a current or future challenge. In case of the presented urban logistics research, the *White Paper on Transport* of the European Commission should be highlighted as motivational relevance point (European Commission, 2011). Rigor can be “achieved by appropriately applying existing foundations and methodologies” (Hevner et al., 2004). In reality, this rigorousness is limited. However, despite the application of IS methods to real-world transportation problems, rigorous processes were applied within the research projects of this dissertation. Nevertheless, due to the increasing number of scientific articles, the existence of synonyms, as well as the transdisciplinary thematic focus on urban transport in this dissertation, there is a possibility that some related literature has not been identified. Moreover, it needs to be considered that for the practical problems at hand, related companies do not scientifically present their own solution methods but rather preserve them as a company secret. While this is often decisive for the company's success, it depicts a limitation regarding availability of corresponding literature, and thus a restriction in rigor.

By exploring relevance and rigor, (potential) research gaps were identified. However, the identification of one or more research gaps is no justification for the development of an artifact to address this lack. An objective decision regarding practical or theoretical benefit of solutions to the problem uncovered, is not or only to a limited extent feasible without the help of expert consultation. In some of the introduced articles, such consultation was possible in connection with the *Initiative Urbane Logistik Hannover*. However, even on the basis of single experts opinions, the objectivity of the decision is limited.

Further limitations focus on the design cycle and its iterative artifact creation. Irrespective of the way the artifact was created, there is no general and objective decision point at which the iterative process should be terminated. The completion of the artifact is usually stopped by subjective decision of the researchers. To avoid this problem, practical users should be involved in the whole development process. A possible solution is the application of a so-called Action Design Research (ADR), in which researchers, developers and end users collaborate to create a useful artifact. ADR is a further enhancement of the DSR approach and is defined as "a research method for generating prescriptive design knowledge through building and evaluating ensemble IT artifacts in an organizational setting" (Sein et al., 2011:4). This collaborative development process eliminates the competing interests of practical users and researchers and ensures practical applicability (Haj-Bolouri et al., 2018). Despite the collaboration with practice partners in the urban transport context, especially within the urban logistics project *USEfUL*, it was not feasible to perform an ADR approach in the course of this dissertation.

To support the development of the artifacts, methods of OR were used. Therefore, optimization models were developed that tackle existent real-world transport problems with the overarching goal of recommendation provision. During this process, several errors can occur (Breitner, 2015): When transferring a real-world problem to a mathematical model, abstraction and modeling errors can appear. When using calculation software to obtain mathematical solutions, discretization errors, calculation errors, as well as inter- and extrapolation errors can result. In order to give recommendations for action based on the results obtained, interpretation errors and logic errors can emerge. If a mathematical problem is integrated within a DSS, programming and relation errors can occur.

Considering the solution methods applied, exact solution methods were used (with the exception of section 6). In case of all developed mathematical models, these are characterized as NP-hard combinatorial optimization problems. This implies, if a problem instance is enlarged, the calculation time increases quadratically. As a result, finding the optimal solution for larger instances is time-consuming. The computing time can be reduced by setting a gap to the optimal solution. In doing so, instead of calculating the optimal solution, the best solution that is below the preset gap is calculated. Another option to achieve faster computing times is the development of heuristic solution methods, as applied in section 6. With a heuristic method, a sufficiently acceptable result can be achieved in an adjustable solution time for the problem at hand. However, a statement regarding the quality of the solution cannot be made because the optimal solution cannot be calculated in this way. Nevertheless, heuristic solution methods are often used in practical applications, since a good solution for the problem at hand can be obtained within a definable short time. Therefore, heuristic solution methods are often used for operative decisions, e.g., routing, to achieve fast results that do not have to be optimal. For long-term decisions, e.g., network planning, exact solution methods are preferred as the decisions strongly influence further operation processes.

A further limitation are restrictions regarding usability of all developed optimization models and, if applicable, associated DSS. To calculate individual scenarios, the decision maker must possess a license for the linked solvers. For most approaches, the solver *IBM ILOG CPLEX* was used, which costs several hundred euros annually in the commercially usable version. The same applies to the heuristic solution method *LocalSolver*, which was presented in section 6.

Another limitation concerning the developed models and DSS is the empirical evaluation of the research artifacts. Based on Hevner et al. (2004:85), evaluation is a "crucial component of the research process" that can be conducted on observational, analytical, experimental, testing, and descriptive level. Following Arnott and Pervan (2012), 86.5% of the DSS related DSR artifacts are not subject to a complete field test. This is also the case for the presented approaches. Due to the lack of a cooperation in the areas of urban mobility and urban logistics, missing reliable field data limit the obtained results as well as the corresponding recommendations. For application examples and benchmarks, estimated parameter values were derived from a variety of sources. In doing so, the developed artifacts were evaluated against the best possible basis by means of demonstrations and applicability checks as well as by comparison to related research approaches.

Finally, the created artifacts (constructs and models) can be classified as nascent design theory, providing knowledge as operational principle or architecture, while benchmarks and sensitivity analyses serve as instantiations of the artifacts (Gregor and Hevner, 2013). As a limitation, no mid-range or grand design theory about the embedded phenomena was developed (Gregor and Hevner, 2013).

Limitations regarding Behavioral Science

In the field of behavioral science, existing scientific models were used, adapted, and extended to measure the acceptance of (potential) customers towards mobility and logistics concepts by conducting online surveys. The TAM2 as well as the UTAUT2 were used as a basis, which are both considered well-established, frequently tested, and confirmed models. Both models are built on the TAM by Davis (1975). The greatest strength of the basic TAM and all its extensions is at the same time its greatest weakness: the inclusion of only few acceptance factors. Based on this simplification, it is not possible to properly differentiate acceptance situations and diverse user groups, as too many determinants of acceptance are neglected (Bagozzi, 2007). Another critique is the isolated consideration of one technology without taking into account technology alternatives as well as user experiences and attitudes towards these alternatives when applying TAM (Lee et al., 2003). This lack of consideration of alternatives can lead to a distorted assessment of the technology under review (Muthitcharoen et al., 2011). Other limitations are "the neglect of group, social, and cultural aspects of decision making" and "the over dependence on a purely deterministic framework without consideration of self-regulation processes" (Bagozzi 2007:245). In the presented acceptance studies in section 5 and section 10, the dataset was limited in terms of German language and a majority of student participants. It thus does not consider a representative sample of the envisaged user population. In particular, Lee et al. (2003) describe a student sample as a major problem with regard to the generalizability of results. In addition, participants differed in their level of knowledge regarding the examined technology, which makes it difficult to achieve uniformity. Despite an appropriate introductory presentation of the investigated concepts, the results obtained can be regarded as biased. To sum up the above-mentioned points, Lee et al. (2003:762) raise the concern of the "tendency to examine only one information system with a homogeneous group of subjects on a single task at a single point of time", which raises a generalization problem of any single study.

In addition, the influence of the intention to use on the actual use assumed in the TAM must be criticized. Due to time intervals between the survey and (potential) actual use, various influencing factors may have a positive or a negative effect on the actual use. Thus, the actual use is not a complete deterministic consequence of the intention to use. The TAM is consequently not suitable for measuring actual use (Bagozzi, 2007; Chuttur, 2009). Given the small sample size, it was necessary to scale up the samples with bootstrapping to measure the influence of the various constructs on BI to use. Due to the reliable arguments within a comparison of different PLS methods by Gefen et al. (2011), PLS-SEM was chosen as the underlying method. Even though the PLS methods are suitable for small sample sizes and the model results showed a high predictive accuracy, it is still questionable whether the existing samples were perhaps too small to find effect relationships that reflect reality. In addition, statistical analysis methods were limited because of the small size and diversity of the samples. This procedure has a substantial influence on the results, as recommendations for action were developed on this foundation. Hence, a large and representative sample size with identical information on the investigated technology should be the basis for the measurement of acceptance. However, this is difficult to achieve (Lee et al., 2003).

Finally, urban mobility and urban logistics concepts were investigated in terms of acceptance by applying techniques that were originally designed for acceptance measurement of technical innovations in a corporate context. Even though this organizational focus has been loosened by the extensions of the TAM, it should be considered whether a dedicated acceptance measurement method for transport contexts could be developed to obtain better results.

11.3. Outlook and Future Research

After presenting future research implications related to each of the articles in sections 2 to 10, this subsection provides a general outlook on the topic of urban transport and its upcoming development.

Without doubt, urbanization as well as the demand for transport, goods, and services will continue to increase. While this dissertation provides decision support for several approaches towards environmentally friendly solutions for urban transport, it cannot solve the massive issues cities will face over the next couple of years. Above discussions illustrate that without drastic measures, it will be difficult to maintain the quality of urban life. Currently, it is impossible to predict whether and how urban transport will develop. A large number of influential factors will shape this development. These factors include the increasing possibilities offered by ICT, which at some stage may help to completely eliminate the need for private vehicles or last mile delivery as we know it today. The possibility of far-reaching regulative interventions by administrative authorities also appear to be an option to realize positive effects within the transport networks. In addition to a complete urban driving ban on conventionally operated vehicles, one example would be the introduction of a city toll, as, for instance, already applied in London (TfL, 2020).

Depending on technical progress, existing infrastructure, legislation, and market demand, certain concepts will emerge. Some urban mobility services, such as station-based carsharing, may be forced from the cities due to more innovative transport solutions. In this regard, the growing appearance of micro-mobility services, such as e-scooters and e-bikes, is worth mentioning. For the cities, it would be desirable to offer a broad mobility subscription based on public transport and individual mobility services that enables inhabitants to move efficiently in urban areas without private vehicle. Within urban logistics, traditional CEP deliveries to customers' homes will be subject to change. Oftentimes, the parcel recipient is not at home resulting in an unsuccessful delivery, increasing operating time and costs for the provider. Consequently, CEP services could be discontinued or minimized via effective price management and other incentives to prefer pick-up points over home delivery. Micro-hubs and central self-collection points are thus likely to increase; besides cost reduction for CEP service providers, positive environmental aspects may emerge. Additionally, new transport vehicles and possibilities of white label deliveries needs to be intensively discussed.

With regard to further research on urban mobility, it is necessary to find appropriate arguments that convince people to replace private vehicles with public and collectively used mobility concepts. For this reason, public transport and NMS (especially e-scooters and ridepooling services) should be further investigated in terms of acceptance, usage, and optimization potential. The same applies to urban logistics concepts. In the context of this dissertation, the *Initiative Urbane Logistik Hannover* should be mentioned, in which relevant CEP service providers are represented. In collaboration with these providers, pilot projects should be accompanied to conduct research in terms of optimization and acceptance based on real data. In addition, the situation and background of the delivery men shall be considered, especially when investigating novel logistics concepts, such as cargo bicycles. Service transports, craftsmen, and freight forwarder transports account for a larger share of the urban road load, which is why alternative logistics concepts should be developed, analyzed, and finally applied also for these industries.

In addition, some general recommendations for future research on optimization issues can be drawn from this dissertation. One important aspect in this regard is the suggested application of an ADR approach. By engaging researchers, developers, and end users collaboratively, the creation of a useful artifact with practical applicability is ensured. Furthermore, practical future approaches, especially regarding large instances of operative decisions, are suggested to focus on the development of heuristic solution approaches. This secures efficiency and practical applicability allowing for feasible everyday usage through adjustable calculation times and sufficiently good results. Regarding behavioral science approaches, the development of transport-specific constructs or even a problem tailored transport TAM or UTAUT could improve future research. Thereby, survey quality could be improved and robustness of derived predictions increased.

To conclude, the knowledge we have today does not suffice for feasible derivations regarding future urban mobility and urban logistics development. It is therefore important to monitor market developments and innovations regarding urban transport concepts and apply methods and models of the transdisciplinary IS domain to achieve more sustainable solutions. Further, it is essential to understand the impact of influential factors, the acceptance, and intention to use of different concepts. As research in this regard is lacking, effects of different measures are unclear, or, at best, rough estimates; to efficiently regulate and steer our cities into a livable and high quality future, stakeholders need to be supported by research in this area.

12. Conclusions

This cumulative dissertation introduces and discusses 13 research articles that I developed collaboratively during my time as a research assistant. In addition to adjacent research areas, the main focus is thereby on urban transport. To address related problems, such as congestion, pollution, or other externalities, the dissertation presents potential solutions, which concurrently support increased economic, social, and environmental sustainability. While part A of the dissertation investigates the topics of carsharing and ridepooling as part of NMS for individual trip purposes, part B describes and analyzes concepts for urban CEP and e-grocery service providers. As theoretical foundation, IS methods of design sciences and behavioral science are applied.

Besides the review of published articles, the overarching purpose of this dissertation is the critical reflection on the research topics of urban mobility and urban logistics in conjunction with the applied methodologies. The corresponding research articles serve as basis to the overall goal of contributing to an improved urban environment and are critically reviewed in a final overall discussion on urban transport. While the presented survey-based studies provide hints regarding the acceptance and potential use of specific concepts, the optimization models tackle current issues of urban transport by providing decision support and recommendations for relevant stakeholders and decision makers. Even though these contributions will not solely solve the present problems, they investigate promising partial concepts and present related suggestions for solutions. However, due to many influencing factors, it is not possible to predict whether the examined approaches can and will be practically and profitably implemented on a larger scale, while taking into account environmental, economic and social aspects.

Although a rethinking in society towards more sustainable solutions in all areas of everyday life can be observed, this awareness does currently not lead to the increased usage of alternative transport concepts, which is essential for a positive transformation. It has also been elaborated that a change requires further incentives to support economic feasibility of switching to alternative urban mobility and logistics options. Yet, this change is important to preserve the earth as our essential basis of life for future generations and maintain the quality of life today. This dissertation therefore points out the huge effects of legal or regulatory elements, which, despite requiring further research, shall and will form a major basis for a better future.

References

Adomavicius, G., Bockstedt, J.C., Gupta, A., Kauffman, R.J. (2008): Making Sense of Technology Trends in the Information Technology Landscape. *Management Information Systems Quarterly*, 32(4), pp. 779-809.

Agarwal, R., Prasad, J. (1999): Are Individual Differences Germane to the Acceptance of New Information Technologies? *Decision Sciences*, 30(2), pp. 361-391.

Agatz, N., Bouman, P., Schmidt, M. (2018): Optimization Approaches for the Traveling Salesman with Drone. *Transportation Science*, 52(4), pp. 965-981.

AIS (2018): AMCIS 2018 Best Paper Winners. Available online https://aisnet.org/news/415076/AMCIS-2018-Best-Paper-Winners.htm, accessed 20.01.2020.

AIS (2019): European Conference on Information Systems. Available online https://aisnet.org/page/ECISPage, accessed 29.01.2020.

AIS (2020a): The International Conference on Information Systems. Available online https://aisnet.org/page/ICISPage, accessed 29.01.2020.

AIS (2020b): The Americas Conference on Information Systems https://aisnet.org/page/AMCISPage, accessed 20.01.2020.

Ajzen, I. (1985): From Intentions to Actions: A Theory of Planned Behaviour. In: Kuhl, J., Beckmann, J. (eds.): Action Control, Springer Series in Social Psychology. Berlin/Heidelberg (Germany): Springer, pp. 11-39.

Ajzen, I. (1991): The Theory of Planned Behavior. *Organization Behavior and Human Decision Processes*, 50(2), pp. 179-211.

Ajzen, I., Madden, T.J. (1986): Prediction of Goal-Directed Behavior: Attitudes, Intentions, and Perceived Behavioral Control. *Journal of Experimental Social Psychology*, 22(5), pp. 453-474.

Alonso-Mora, J., Samaranayake, S., Wallar, A., Frazzoli, E., Rus, D. (2017): On-Demand High-Capacity Ride-Sharing via Dynamic Trip-Vehicle Assignment. In: Proceedings of the National Academy of Sciences 2017, 115(3), pp. 462-467.

Arndt, W.-H. (2010): Optimierungspotenziale im Wirtschaftsverkehr durch besteller-seitige Kooperation. Doctoral Dissertation, Berlin (Germany): Faculty V of Mechanical Engineering and Transport Systems, Technische Universität Berlin.

Arnott, D., Pervan, G. (2012): Design Science in Decision Support Systems Research: An Assessment using the Hevner, March, Park, and Ram Guidelines. *Journal of the Association for Information Systems*, 13(11), pp. 923-949.

Awasthi, A., Breuil, D., Chauhan, S.S., Parent, M., Reveillere, T. (2007): A Multicriteria Decision Making Approach for Carsharing Stations Selection. *Journal of Decision Systems*, 16(1), pp. 57-78.

Ayanso, A., Lertwachara, K., Vachon, F. (2011): Design and Behavioral Science Research in Premier IS Journals: Evidence from Database Management Research. In: Jain, H., Sinha, A.P., Vitharana, P. (eds.): Service-Oriented Perspectives in Design Science Research, DESRIST 2011, Lecture Notes in Computer Science (6629). Berlin/Heidelberg (Germany): Springer, pp. 138-152.

Bagozzi, R.P. (2007): The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift. *Journal of the Association for Information Systems*, 8(4), article 3.

Barone, V., Crocco, F., Mongelli, D.W.E. (2014): Models of Choice between Shopping and E-Shopping. *Applied Mechanics and Materials*, 442, pp. 607-616.

Barth, M., Shaheen, S.A. (2002): Shared-Use Vehicle Systems – Framework for Classifying Carsharing, Station Cars, and Combined Approaches. *Transportation Research Record*, 1791, pp. 105-112.

BBC (2014): Paris Car Ban Imposed after Pollution Hits High. Available online https://www.bbc.com/news/world-europe-26599010, accessed 28.01.2020.

Behrends, B., Lindholm, M., Woxenius, J. (2008): The Impact of Urban Freight Transport: A Definition of Sustainability from an Actor's Perspective. *Transportation Planning and Technology*, 31(6), pp. 693-713.

Benbasat, I., Barki, H. (2007): Quo Vadis TAM? *Journal of the Association for Information Systems*, 8(4), article 7.

Benbasat, I., Zmud, R.W. (1999): Empirical Research in Information Systems: The Practice of Relevance. *Management Information Systems Quarterly*, 23(1), pp. 3-16.

BerlKönig (2019). Berlin fährt BerlKönig – Zwischenbilanz nach den ersten sechs Monaten. Available online https://www.berlkoenig.de/zwischenbilanz-nach-den-ersten-sechs-monaten/, accessed 21.01.2020.

Bielli, M., Bielli, A., Rossi, R. (2011): Trends in Models and Algorithms for Fleet Management. *Procedia - Social and Behavioral Sciences*, 20, pp. 4-18.

Bischoff, J., Kaddoura, I., Maciejewski, M., Nagel, K. (2018): Simulation-Based Optimization of Service Areas for Pooled Ride-Hailing Operators. *Procedia Computer Science*, 130, pp. 816-823.

Bitran, G., Caldentey, R. (2004): An Overview of Pricing Models for Revenue Management. *Manufacturing & Service Operations Management*, 5(3), pp. 203-229.

Blacha, P., Kraft, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H. (2019): Analysis of Augmented Reality Applications within the German Automotive Industry. *IWI Discussion Paper Series*, 88, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Bortz, J., Döring, N. (2006): *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler* (4th ed.). Heidelberg (Germany): Springer.

Boyacı, B., Zografos, K.G., Geroliminis, N. (2015): An Optimization Framework for the Development of Efficient One-Way Car-Sharing Systems. *European Journal of Operational Research*, 240(3), pp. 718-733.

Boysen, N., Schwerdfeger, S., Weidinger, F. (2018): Scheduling Last-Mile Deliveries with Truck-based Autonomous Robots. *European Journal of Operational Research*, 271(3), pp. 1085-1099.

Brandstätter, G., Kahr, M., Leitner, M. (2017): Determining Optimal Locations for Charging Stations of Electric Car-Sharing Systems under Stochastic Demand. *Transportation Research Part B*, 104, pp. 17-35.

Breitner, M.H. (2015): Optionen und andere Derivate bepreisen und optimieren: Die WARRANT-PRO Suite. Lecture slides, Institut für Wirtschaftsinformatik, Leibniz

Universität Hannover. Available online https://docplayer.org/2205362-Optionen-und-andere-derivate-bepreisen-und-optimieren-die-warrant-pro-suite.html, accessed 10.02.2020.

Broihan, J., Möller, M., Kühne, K., Sonneberg, M.-O., Breitner, M.H. (2018): Revenue Management Meets Carsharing: Optimizing the Daily Business. In: Fink, A., Fügenschuh, A., Geiger, M.J. (eds.): Operations Research Proceedings 2016. Basel (Switzerland): Springer International Publishing, pp. 421-427.

Carlsson, J.G., Song, S. (2017): Coordinated Logistics with a Truck and a Drone. *Management Science*, 64(9), pp. 4052-4069.

Castrellón-Torres, J.P., Chaparro, J.S.T., Barrera, N.E.M., Acosta, J.H.T., Jaimes, W.A. (2018): Information Technology in City Logistics: A Decision Support System for Off-Hour Delivery Programs. In: Valencia-García, R., Paredes-Valverde, M.A., Pilar Salas-Zárate, M., Alor-Hernández, G. (eds.): Exploring Intelligent Decision Support Systems. Cham (Switzerland): Springer, pp. 221-238.

Chan, N.D., Shaheen, S.A. (2012): Ridesharing in North America: Past, Present, and Future. *Transportation Reviews*, 32(1), pp. 93-112.

Chen, M.H., Jauhri, A., Shen, J.P. (2017): Data Driven Analysis of the Potentials of Dynamic Ridepooling. In: Proceedings of the 10th ACM SIGSPATIAL Workshop on Computational Transportation Science, Redondo Beach, California, USA, pp. 7-12.

Cheng, T.C.E., Lam, D.Y.C., Yeung, A.C.L. (2006): Adoption of Internet Banking: An Empirical Study in Hong Kong. *Decision Support Systems*, 42(3), pp. 1558-1572.

Chuttur, M. (2009): Overview of the Technology Acceptance Model: Origins, Developments and Future Directions. *Working Papers on Information Systems*, 9(37), pp. 9-37.

Clarivate Analytics (2019): Welcome to Journal Citation Reports. Available online https://jcr.clarivate.com/IC2JCRDownload.action, accessed 15.01.2020.

Clewlow, R.R. (2016): Carsharing and Sustainable Travel Behavior: Results from the San Francisco Bay Area. *Transport Policy*, 51, pp. 158-164.

Clewlow, R.R., Mishra, G.S. (2017): Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States. Research Report UCD-ITS-RR-17-07, Davis (California, USA): Institute of Transportation Studies, University of California.

Cordeau, J.-F., Gendreau, M., Laporte, G. (1997): A Tabu Search Heuristic for Periodic and Multi-Depot Vehicle Routing Problems. *Networks*, 30(2), pp. 105-119.

Cordeau, J.-F., Gendreau, M., Laporte, G., Potvin, J.V., Semet, F. (2002): A Guide to Vehicle Routing Heuristics. *Journal of the Operational Research Society*, 53(5), pp. 512-522.

Cordeau, J.-F., Maischberger, M. (2012): A Parallel Iterated Tabu Search Heuristic for Vehicle Routing Problems. *Computers & Operations Research*, 39(9), pp. 2033-2050.

Correia, G.H., Antunes, A.P. (2012): Optimization Approach to Depot Location and Trip Selection in One-Way Carsharing Systems. *Transportation Research Part E*, 48(1), pp. 233-247.

Costain, C., Ardron, C., Habib, K.N. (2012): Synopsis of Users' Behaviour of a Carsharing Program: A Case Study in Toronto. *Transportation Research Part A*, 46(3), pp. 421-434.

Dang, V.K., Sonneberg, M.-O., Breitner, M.H. (2016): Analyse innovativer Logistikkonzepte für urbane Paketdienstleister. *IWI Discussion Paper Series*, 80, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Davis, F.D. (1985): A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results. Doctoral Dissertation, Cambridge (Massachusetts, USA): Massachusetts Institute of Technology.

Davis, F.D., Bagozzi, R.P., Warshaw, P.R. (1989): User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science*, 35(8), pp. 982-1003.

De Oliveira, L.M., Morganti, E., Dablanc, L., De Oliveira, R.L.M. (2017): Analysis of the Potential Demand of Automated Delivery Stations for E-Commerce Deliveries in Belo Horizonte, Brazil. *Research in Transportation Economics*, 65, pp. 34-43.

Dedrick, J. (2010): Green IS: Concepts and Issues for Information Systems Research. *Communications of the Association for Information Systems,* 27, pp. 173-184.

Degirmenci, K., Breitner, M.H. (2014): Carsharing: A Literature Review and a Perspective for Information Systems Research. In: Suhl, L., Kundisch, D., Beckmann, L. (eds.): MKWI 2014 - Multikonferenz Wirtschaftsinformatik. Paderborn (Germany): Universitätsbibliothek Paderborn, pp. 962-979.

Desouza, K.C., El Sawy, O.A., Galliers, R.D., Loebbecke, C., Watson, R.T. (2006): Beyond Rigor and Relevance Towards Responsibility and Reverberation: Information Systems Research that Really Matters. *Communications of the Association for Information Systems*, 17(1), article 16.

Digiesi, S., Fanti, M.P., Mummolo, G., Silvestri, B. (2017): Externalities Reduction Strategies in Last Mile Logistics: A Review. In: Proceedings of IEEE International Conference on Service Operations and Logistics and Informatics 2017, Bari, Italy, pp. 248-253.

Drexl, M. (2012): Rich Vehicle Routing in Theory and Practice. *Logistics Research*, 5, pp. 47-63.

Eekhoff, I., Günther, J., Keuerleber, M., Arnd, M., Wagner, A. (2015): *Consulting in Sustainable Mobility – Made in Germany*. Eschborn (Germany): German Partnership for Sustainable Mobility.

Ehrler, V.C., Hebes, P. (2012): Electromobility For City Logistics - The Solution To Urban Transport Collaps? An Analysis Beyond Theory. *Procedia - Social and Behavioral Sciences*, 48, pp. 786-795.

Eksioglu, B., Vural, A.V., Reisman, A. (2009): The Vehicle Routing Problem. A Taxonomic Review. *Computers & Industrial Engineering*, 57(4), pp. 1472-1483.

El Fassi, A., Awasthi, A., Viviani, M. (2012): Evaluation of Carsharing Network's Growth Strategies through Discrete Event Simulation. *Expert Systems with Applications*, 39(8), pp. 6692-6705.

European Commission (2011): *White Paper on Transport - Roadmap to a Single European Transport Area - Towards a Competitive and Resource-Efficient Transport System*. Luxemburg (Luxemburg): Publications Office of the European Union.

European Commission (2013): *A Call to Action on Urban Logistics*. European Commission Staff Working Document, Brussels (Belgium): European Commission.

European Commission (2019): Urban Mobility in the EU. Available online https://ec.europa.eu/transport/urban/consultations/urban-mobility-eu_en, accessed 15.01.2020.

European Commission (2020): Urban Logistics. Available online https://ec.europa.eu/transport/themes/urban/urban_mobility/urban_mobility_actions/urban-logistics_en, accessed 15.01.2020

Ferrandez, S.M., Harbison, T., Weber, T., Sturges, R., Rich, R. (2016): Optimization of a Truck-Drone in Tandem Delivery Network using K-Means and Genetic Algorithm. *Journal of Industrial Engineering and Management*, 9(2), pp. 374-388.

Figliozzi, M., Tipagornwong, C. (2017): Impact of Last Mile Parking Availability on Commercial Vehicle Costs and Operations. *Supply Chain Forum: An International Journal*, 18(2), pp. 60-68.

Financial Times (2017): Diesel Cars to Be Banned from Oslo City Centre. Available online https://www.ft.com/content/644f8cfa-db60-11e6-86ac-f253db7791c6, accessed 28.01.2020.

Fishbein, M., Ajzen, I. (1975): *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Reading (Massachusetts, USA): Addison-Wesley.

Fossheim, K., Andersen, J. (2017): Plan for Sustainable Urban Logistics – Comparing between Scandinavian and UK Practices. *Transport Research Review*, 9(4), article 52.

Frattini, F., Bianchi, M., De Massis, A., Sikimic, U. (2014): The Role of Early Adopters in the Diffusion of New Products: Differences between Platform and Nonplatform Innovations. *Journal of Product Innovation Management*, 31(3), pp. 466-488.

Furuhata, M., Dessouky, M., Ordóñez, F., Brunet, M.E., Wang, X., Koenig, S. (2013): Ridesharing: The State-of-the-Art and Future Directions. *Transportation Research Part B*, 57, pp. 28-46.

Gardi, F., Benoist, T., Darlay, J., Estellon, B., Megel, R. (2014): Local Search for 0-1 Nonlinear Programming. In: Gardi, F., Benoist, T., Darlay, J., Estellon, B., Megel, R. (eds.): Mathematical Programming Solver Based on Local Search. Hoboken (New Jersey, USA): John Wiley & Sons, pp. 29-51.

Gebski, S.A., Czerwinski, P., Leyerer, M., Sonneberg, M.-O., Breitner, M.H. (2018): Ein Entscheidungsunterstützungssystem zur Tourenplanung am Beispiel eines innovativen Lebensmittel-Lieferkonzeptes. In: Proceedings of the 10th Multikonferenz Wirtschaftsinformatik (MKWI) 2018, Lüneburg, Germany, pp. 21-32.

Gefen, D., Karahanna, E., Straub, D.W. (2003): Trust and TAM in Online Shopping: An Integrated Model. *Management Information Systems Quarterly*, 27(1), pp. 51-90.

Gefen, D., Rigdon, E.E., Straub, D. (2011): Editor's Comments: An Update and Extension to SEM Guidelines for Administrative and Social Science Research. *Management Information Systems Quarterly*, 35(2), pp. 3-14.

Gevaers, R., van de Voorde, E., Vanelslander, T. (2009): Characteristics of Innovations in Last-Mile Logistics - Using Best Practices, Case Studies and Making the Link with Green and Sustainable Logistics. Antwerp (Netherlands): Department of Transport and Regional Economics, University of Antwerp.

Gholami, R., Watson, R.T., Molla, A., Hasan, H., Bjørn-Andersen, N. (2016): Information Systems Solutions for Environmental Sustainability: How Can We Do More? *Journal of the Association for Information Systems*, 17(8), pp. 521-536.

Giang, P.T., Trang, P.T., Yen, V.T. (2017): An Examination of Factors Influencing the Intention to Adopt Ride-Sharing Applications. A Case Study in Vietnam. *Imperial Journal of Interdisciplinary Research*, 3(10), pp. 618-623.

Gilibert, M., Ribas, I. (2019): Main Design Factors for Shared Ride-Hailing Services from a User Perspective. *International Journal of Transport Development and Integration*, 3(3), pp. 195-206.

Gregor, S., Hevner, A.R. (2013): Positioning and Presenting Design Science Research for Maximum Impact. *Management Information Systems Quarterly*, 37(2), pp. 337-355.

Guerriero, F., Olivito, F. (2014): Revenue Models and Policies for the Car Rental Industry. *Journal of Mathematical Modelling and Algorithms in Operations Research*, 13(3), pp. 247-282.

Guhr, N., Sonneberg, M.-O., Passlick, J.H., Werth, O., Breitner, M.H. (2020): Trends of Top Information Research by Region, Outlet, and Emergence. *Submitted to* Journal of Information Systems and Technology Management. *Under review.*

Hair Jr., J.F., Hult, G.T.M., Ringle, C., Sarstedt, M.J. (2016): *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2nd ed.). Thousand Oaks (California, USA): SAGE Publications.

Hair Jr., J.F., Sarstedt, M., Ringle, C.M., Mena, J.A. (2012): An Assessment of the Use of Partial Least Squares Structural Equation Modeling in Marketing Research. *Journal of the Academy of Marketing Science*, 40(3) pp. 414-433.

Haj-Bolouri, A., Purao, S., Rossi, M., Bernhardsson, L. (2018): Action Design Research in Practice: Lessons and Concerns. In: Proceedings of the 27th European Conference on Information Systems (ECIS) 2018, Portsmouth, United Kingdom, article 131.

Hänsel, A., Mederer, M., Schmidt, H. (2012): Revenue Management in the Car Rental Industry: A Stochastic Programming Approach. *Journal of Revenue and Pricing Management*, 11(1), pp. 99-108.

Hartl, R.F., Hasle, G., Janssens, G.K. (2006): Special Issue on Rich Vehicle Routing Problems. *Central European Journal of Operations Research*, 14(2), pp. 103-104.

Hasle, G., Kloser, O. (2007): Industrial Vehicle Routing. In: Hasle, G., Lie, K.-A., Quak, E. (eds.): Geometric Modelling, Numerical Simulation, and Optimization. Berlin/Heidelberg (Germany): Springer, pp. 397-436.

Hassan, N.R. (2014): Value of IS Research: Is there a Crisis? *Communications of the Association for Information Systems*, 34(41), pp. 801-816.

He, Z., Haasis, H.D. (2019): Integration of Urban Freight Innovations: Sustainable Inner-Urban Intermodal Transportation in the Retail/Postal Industry. *Sustainability*, 11(6), article 1749.

Heinzl, A., Schoder, D., Frank, U. (2008): WI-Mitteilungen der WKWI und des GI-FB WI. *Wirtschaftsinformatik*, 2, pp. 155-163.

Hennig-Thurau, T., Sattler, H., Dyckhoff, H., Franke, N., Schreyögg, G. (2015): VHB-JOURQUAL3. Available online https://vhbonline.org/vhb4you/vhb-jourqual/vhb-jourqual-3/gesamtliste, accessed 15.01.2020.

Henseler, J., Ringle, C.M., Sarstedt, M.J. (2015): A New Criterion for Assessing Discriminant Validity in Variance-based Structural Equation Modeling. *Journal of the Academy of Marketing Science*, 43(1), pp. 115-135.

Hevner, A.R. (2007): A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems*, 19(2:4), pp. 87-92.

Hevner, A.R., March, S.T., Park, J., and Ram, S. (2004): Design Science in Information Systems Research. *Management Information Systems Quarterly*, 28(1), pp. 75-105.

HICSS (2020): About HICSS. Available online https://hicss.hawaii.edu/about/, accessed 20.01.2020.

Holguin-Veras, J., Hodge, S., Wojtowicz, J., Singh, C., Wang, C., et al. (2018): The New York City Off-Hour Delivery Program: A Business and Community-Friendly Sustainability Program. *INFORMS Journal on Applied Analytics*, 48(1), pp. 70-86.

Holland, C., Levis, J., Nuggehalli, R., Santilli, R., Winters, J. (2017): UPS Optimizes Delivery Routes. *INFORMS Journal on Applied Analytics*, 47(1), pp. 8-23.

Hübner, A., Kuhn, H., Wollenburg, J. (2016): Last Mile Fulfilment and Distribution in Omni-Channel Grocery Retailing: A Strategic Planning Framework. *International Journal of Retail & Distribution Management*, 44(3), pp. 228-247.

ICIS (2015): Welcome! Available online http://archives.aisconferences.org/icis2015/icis2015/, accessed 29.01.2020.

ICOR (2016): Annual International Conference of the German Operations Research Society – OR 2016. Available online http://or2016.de/, accessed 29.01.2020.

IGD (2018): Leading Global Online Grocery Markets to Create a $227bn Growth Opportunity by 2023. Available online https://www.igd.com/about-us/media/pressreleases/press-release/t/leading-global-online-grocery-markets-to-create-a-227bn-growth-opportunity-by-2023/i/20396, accessed 15.02.2020.

Iwan, S., Kijewska, K., Lemke, J. (2016): Analysis of Parcel Lockers' Efficiency as the Last Mile Delivery Solution – The Results of the Research in Poland. *Transportation Research Procedia*, 12, pp. 644-655.

Joerss, M., Schröder, J., Neuhaus, F., Klink, C., Mann, F. (2016): *Parcel Delivery - The Future of Last Mile*. Beijing (China): McKinsey&Company.

Juschten, M., Ohnmacht, T., Thao, V.T., Gerike, R., Hössinger, R. (2019): Carsharing in Switzerland: Identifying New Markets by Predicting Membership based on Data on Supply and Demand. *Transportation*, 46(4), pp. 1171-1194.

Kamargianni, M., Matyas, M. (2017): The Business Ecosystem of Mobility-as-a-Service. In: Crites, J.M. (ed.): Proceedings of the 96th Transportation Research Board Annual Meeting, 8-12 January 2017, Washington DC (USA), article 6538.

Kitchenham, B., Brereton, O.P., Budgen, D., Turner, M., Bailey, J., Linkman, S. (2009): Systematic Literature Reviews in Software Engineering - A Systematic Literature Review. *Information and Software Technology*, 51(1), pp. 7-15.

Koç, Ç., Bektaş, T., Jabali, O., Laporte, G. (2016): The Impact of Depot Location, Fleet Composition and Routing on Emissions in City Logistics. *Transportation Research Part B*, 84, pp. 81-102.

König, A., Bonus, T., Grippenkoven, J. (2018): Analyzing Urban Residents' Appraisal of Ridepooling Services Attributes with Conjoint Analysis. *Sustainability*, 10(10), article 3711.

Kuechler, B., Vaishnavi, V., Kuechler, W.L. (2007): Design [Science] Research in IS: A Work in Progress. In: Proceedings of the 2nd International Conference on Design Science Research in Information Systems and Technology, Pasadena, California, USA.

Kühne, K., Sonneberg, M.-O., Breitner, M.H. (2017): Ecological & Profitable Carsharing Business: Emission Limits & Heterogeneous Fleets. In: Proceedings of the 25th European Conference on Information Systems (ECIS) 2017, Guimarães, Portugal, article 80.

Kummer, S., Dobrovnik, M., Herold, D.M., Hribernik, M., Mikl, J. (2019): Citylogistik Wien: Der Einfluss von Paketdienstleistern auf den Gesamtverkehr. Endbericht der Studie. Available online https://epub.wu.ac.at/7432/, accessed 15.02.2020.

Kuntzky, K., Wittke, S., Herrmann, C. (2013): Car and Ride Sharing Concept as a Product Service System – Simulation as a Tool to Reduce Environmental Impacts. In: Shimomura, Y., Kimita, K. (eds.): The Philosopher's Stone for Sustainability. Berlin/Heidelberg (Germany): Springer, pp. 381-386.

Kwon, O., Song, M.S. (2012): Understanding Customer Intention to Adopt Sustainable IT Products through Two Dimensional Value Structure and Perceived Sustainability. *Asia Pacific Journal of Information Systems*, 22(3), pp. 29-52.

Lahyani, R., Khemakhem, M., Semet, F. (2015): Rich Vehicle Routing Problems: From a Taxonomy to a Definition. *European Journal of Operational Research*, 241, pp. 1-14.

Lai, K., Ng, W. (2005): A Stochastic Approach to Hotel Revenue Optimization. *Computers & Operations Research*, 32, pp. 1059-1072.

Laporte, G. (2009): Fifty Years of Vehicle Routing. *Transportation Science*, 43, pp. 408-416.

Lee, J., Lee, D., Park, Y., Lee, S., Ha, T. (2019): Autonomous Vehicles can be Shared, but a Feeling of Ownership is Important: Examination of the Influential Factors for Intention to Use Autonomous Vehicles. *Transportation Research Part C*, 107, pp. 411-422.

Lee, M.-C. (2009): Factors Influencing the Adoption of Internet Banking: An Integration of TAM and TPB with Perceived Risk and Perceived Benefit. *Electronic Commerce Research and Applications*, 8(3), pp. 130-141.

Lee, Y., Kozar, K.A., Larsen, K.R. (2003): The Technology Acceptance Model: Past, Present, and Future. *Communications of the Association for Information Systems*, 12(1), article 50.

Lenstra, J.K., Kan, A.H.G. (1981): Complexity of Vehicle Routing and Scheduling Problems. *Networks*, 11(2), pp. 221-227.

Lerner, W. (2011): *The Future of Urban Mobility: Towards Networked, Multimodal Cities of 2050*. Frankfurt (Germany): Arthur D. Little.

Leyerer, M., Sonneberg, M.-O., Breitner, M.H. (2018): Decision Support for Urban E-Grocery Operations. In: Proceedings of the 24th Americas Conference on Information Systems (AMCIS) 2018, New Orleans, Louisiana, USA.

Leyerer, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H. (2019b): Decision Support for Sustainable and Resilience-Oriented Urban Parcel Delivery. *EURO Journal on Decision Processes*, 7, pp. 267-300.

Leyerer, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H. (2020): Shortening the Last Mile of E-Grocery: Optimizing a New Logistics Concept for Urban Areas. *Smart Cities*, 3(3), 585-603.

Leyerer, M., Sonneberg, M.-O., Heumann, M., Kammann, T., Breitner, M.H. (2019a): Individually Optimized Commercial Road Transport: A Decision Support System for Customizable Routing Problems. *Sustainability*, 11(20), article 5544.

Ludwig, T., Pipek, V. (2019): Tagungsband WI 2019. Available online https://wi2019.de/tagungsband/, accessed 29.01.2020.

Malhotra, A., Melville, N.P., Watson, R.T. (2014): Spurring Impactful Research on Information Systems for Environmental Sustainability. *Management Information Systems Quarterly*, 37(4), pp. 1265-1274.

Manerba, D., Mansini, R., Zanotti, R. (2018): Attended Home Delivery: Reducing Last-Mile Environmental Impact by Changing Customer Habits. *IFAC PapersOnLine*, 51(5), pp. 55-60.

March, S.T., Smith, G.S. (1995): Design and Natural Science Research on Information Technology. *Decision Support Systems*, 15(4), pp. 251-266.

McLoed, S., Schapper, J.H.M., Curtis, C., Graham, G. (2019): Conceptualizing Freight Generation for Transport and Land Use Planning: A Review and Synthesis of the Literature. *Transport Policy*, 74, pp. 24-34.

Merlin, L.A. (2019): Transportation Sustainability Follows from More People in Fewer Vehicles, not Necessarily Automation. *Journal of the American Planning Association*, 85(4), pp. 501-510.

Mkansi, M., Eresia-Eke, C., Emmanuel-Ebikake, O. (2018): E-Grocery Challenges and Remedies: Global Market Leaders Perspective. *Cogent Business & Management*, 5, pp. 1-28.

Morency, C., Trépanier, M., Martin, B. (2008): Object-Oriented Analysis of Carsharing System. *Transportation Research Record*, 2063, pp. 105-112.

Moutaoukil, A., Neubert, G., Derrouiche, R. (2015): Urban Freight Distribution: The Impact of Delivery Time on Sustainability. *IFAC PapersOnLine*, 48(3), pp. 2368-2373.

Münzel, K., Boon, W., Frenken, K., Vaskelainen, T. (2018): Carsharing Business Models in Germany: Characteristics, Success and Future Prospects. *Information Systems and e-Business Management*, 16(2), pp. 271-291.

Münzel, K., Piscicelli, L., Boon, W., Frenken, K. (2019): Different Business Models – Different Users? Uncovering the Motives and Characteristics of Business-to-Consumer and Peer-to-Peer Carsharing Adopters in the Netherlands. *Transportation Research Part D*, 73, pp. 276-306.

Murray, C.C., Chu, A.G. (2015): The Flying Sidekick Traveling Salesman Problem: Optimization of Drone-Assisted Parcel Delivery. *Transportation Research Part C*, 54, pp. 86-109.

Musso, A., Corazza, M.V., Tozzi, M. (2012): Car Sharing in Rome: A Case Study to Support Sustainable Mobility. *Procedia - Social and Behavioral Sciences*, 48, pp. 3482-3491.

Muthitcharoen, A.M., Palvia, P.C., Grover, V. (2011): Building a Model of Technology Preference: The Case of Channel Choices. *Decision Sciences*, 42(1), pp. 205-237.

Myers, M.D. (2013): *Qualitative Research in Business & Management* (2nd ed.). London (United Kingdom): Sage Publications.

Nakamura, H., Uchida, A., Managi, S. (2019): Relationship Between Community-Sharing of New Personal Transportation and Local Residents' Daily Life Consciousness. *Economic Analysis and Policy*, 61, pp. 104-110.

Neels, B., Sonneberg, M.-O., Breitner, M.H. (2016): IKT-basierte Geschäftsmodellinnovationen im Gütertransport: Marktübersicht und Analyse. *IWI Discussion Paper Series*, 78, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Niehaus, A. (2005): Analyse der Bewertung verschiedener Zustellungsoptionen im B2C E-Commerce. Vienna (Austria): Schriftenreihe des Instituts für Transportwirtschaft und Logistik, Vienna University of Economics and Business.

Nourinejad, M., Roorda, M.J. (2014): A Dynamic Carsharing Decision Support System. *Transportation Research Part E*, 66, pp. 36-50.

Osswald, S., Wurhofer, D., Trösterer, S., Beck, E., Tscheligi, M. (2012): Predicting Information Technology Usage in the Car: Towards a Car Technology Acceptance Model. In: Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications 2012, Washington DC, USA, pp. 51-58.

Pavlou, P.A. (2003): Consumer Acceptance of Electronic Commerce: Integrating Trust and Risk with the Technology Acceptance Model. *International Journal of Electronic Commerce*, 7(3), pp. 101-134.

Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S. (2007): A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems*, 24(3:3), pp. 45-77.

Peres, R., Muller, E., Mahajan, V. (2010): Innovation Diffusion and New Product Growth Models: A Critical Review and Research Directions. *International Journal of Research in Marketing*, 27(2), pp. 91-106.

Pisinger, D., Ropke, S. (2007): A General Heuristic for Vehicle Routing Problems. *Computers & Operations Research*, 34(8), pp. 2403-2435.

Power, D.J. (2002): *Decision Support Systems: Concepts and Resources for Managers*. Westport (Connecticut, USA): Greenwood Publishing Group.

Premkumar, G., Bhattacherjee, A. (2008): Explaining Information Technology Usage: A Test of Competing Models. *Omega*, 36(1), pp. 64-75.

Prodhon, C., Prins, C. (2014): A Survey of Recent Research on Location-Routing Problems. *European Journal of Operational Research*, 238, pp. 1-17.

Rademeyer, A.L., Lubinsky, D.J. (2017): A Decision Support System for Strategic, Tactical and Operational Visit Planning for On-The-Road Personnel. *South African Journal of Industrial Engineering*, 28, pp. 57-72.

Ranieri, L., Digiesi, S., Silvestri, B., Roccotelli, M. (2018): A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision. *Sustainability*, 10(3), article 782.

Rayle, L., Dai, D., Chan, N., Cervero, R., Shaheen, S. (2016): Just a Better Taxi? A Survey-based Comparison of Taxis, Transit, and Ridesourcing Services in San Francisco. *Transport Policy*, 45, pp. 168-178.

Remane, G., Nickerson, R., Hanelt, A., Tesch, J.F., Kolbe, L.M. (2016): A Taxonomy of Carsharing Business Models. In: Proceedings of the 37th International Conference on Information Systems 2016, Dublin, Ireland.

Reuters (2018): Factbox: German Cities Ban Older Diesel Cars. Available online https://www.reuters.com/article/us-germany-emissions-factbox/factbox-german-cities-ban-older-diesel-cars-idUSKCN1NK28L, accessed 28.01.2020.

Rhee, J., Alfian, G., Yoon, B. (2014): Application of Simulation Method and Regression Analysis to Optimize Car Operations in Carsharing Services: A Case Study in South Korea. *Journal of Public Transportation*, 17(1), pp. 121-160.

Rickenberg, T.A., Gebhardt, A., Breitner, M.H. (2013): A Decision Support System for the Optimization of Car Sharing Stations. In: Proceedings of the 21st European Conference on Information Systems, Utrecht, Netherlands, article 207.

Ringle, C.M., Sarstedt, M., Straub, D.W. (2012): A Critical Look at the Use of PLS-SEM in MIS Quarterly. *Management Information Systems Quarterly*, 36(1), pp. 3-14.

Rogers, E.M. (1962): *Diffusion of Innovations*. New York City (New York, USA): Free Press.

Rogers, E.M. (2003): *Diffusion of Innovations* (5th ed.). New York City (New York, USA): Free Press.

Rondan-Cataluña, F.J., Arenas-Gaitán, J., Ramírez-Correa, P.E. (2015): A Comparison of the Different Versions of Popular Technology Acceptance Models. *Kybernetes*, 44(5), pp. 788-805.

Ruangkanjanases, A., Techapoolphol, C. (2018): Adoption of E-Hailing Applications: A Comparative Study between Female and Male Users in Thailand. *Journal of Telecommunication, Electronic and Computer Engineering*, 10, pp. 43-48.

Sanguinetti, A., Kurani, K., Ferguson, B. (2019): Is it Ok to Get in a Car with a Stranger? Risks and Benefits of Ride-Pooling in Shared Automated Vehicles. Research Report UC-ITS-2018-20, Davis (California, USA): Institute of Transportation Studies, University of California.

Schäfer, P.K., Väth, J., Bierwirth, B. (2019): *Analyse des Wirtschaftsverkehrs in der Innenstadt der Landeshauptstadt Wiesbaden*. Frankfurt (Germany): Research Lab for Urban Transport, Frankfurt University of Applied Sciences.

Schaller, B. (2018): The New Automobility: Lyft, Uber and the Future of American Cities. Available online http://www.schallerconsult.com/rideservices/automobility.pd, accessed 21.01.2020.

Schmidt, G., Wilhelm, W.E. (2000): Strategic, Tactical and Operational Decisions in Multi-National Logistics Networks: A Review and Discussion of Modelling Issues. *International Journal of Production Research*, 38(7), pp. 1501-1523.

Schmöller, S., Bogenberger, K. (2020): Carsharing: An Overview on What We Know. In: Antoniou, C., Efthymiou, D., Chaniotakis, E. (eds.): Demand for Emerging Transportation Systems – Modeling Adoption, Satisfaction, and Mobility Patterns. Amsterdam (Netherlands): Elsevier, pp. 211-226.

Schwaer, H., Meyer, C. (2019): Warum sich Ride-Pooling-Anbieter in Deutschland schwer tun. Available online https://www.gruenderszene.de/business/ride-pooling-probleme, accessed 21.01.2020.

Seidel, S., Bharati, P., Fridgen, G., Watson, R.T., Albizri, A., et al. (2017): The Sustainability Imperative in Information Systems Research. *Communications of the Association for Information Systems*, 40(3), pp. 40-52.

Seidel, S., Mareï, N., Blanquart, C. (2016): Innovations in E-Grocery and Logistics Solutions for Cities. *Transportation Research Procedia*, 12, pp. 825-835.

Sein, M.K., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R. (2011): Action Design Research. *Management Information Systems Quarterly*, 35(1), pp. 37-56.

Shaheen, S.A., Cohen, A.P., Chung, M.S. (2009): North American Carsharing: A Ten-Year Retrospective. *Transportation Research Record*, 2110, pp. 35-44.

Shavarani, S.M., Nejad, M.G., Rismanchian, F., Izbirak, G. (2015): Application of Hierarchical Facility Location Problem for Optimization of a Drone Delivery System: A Case Study of Amazon Prime Air in the City of San Francisco. *International Journal of Advanced Manufacturing Technology*, 95(9-12), pp. 3141-3153.

SIGGreen (2018): Introduction to Green Information Systems (Green IS). Available online https://communities.aisnet.org/siggreen/new-item5/new-item4, accessed 28.01.2020.

Simoni, M.D., Bujanovic, P., Boyles, S.D., Kutanoglu, E. (2018): Urban Consolidation Solutions for Parcel Delivery Considering Location, Fleet and Route Choice. *Case Studies on Transport Policy*, 6(1), pp. 112-124.

Sonneberg, M.-O., Breitner, M.H. (2020): Station-based Electric Carsharing: A Decision Support System for Network Generation. In: Degirmenci, K., Cerbe, T.M., Pfau, W.E. (eds.): Electric Vehicles in Shared Fleets: Mobility Management, Business Models and Decision Support Systems. Singapore: World Scientific. *Forthcoming.*

Sonneberg, M.-O., Hempen, M., Vollert, J., Breitner, M.H. (2019d): Chancen, Herausforderungen und Voraussetzungen von Cargotram-Projekten. *IWI Discussion Paper Series*, 93, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Sonneberg, M.-O., Kühne, K., Breitner, M.H. (2015): A Decision Support System for the Optimization of Electric Car Sharing Stations. In: Proceedings of the 36th International Conference on Information Systems (ICIS) 2015, Fort Worth, Texas, USA.

Sonneberg, M.-O., Kühne, K., Breitner, M.H. (2020): Optimization of Station-based Carsharing Networks: Increasing Sustainability through Heterogeneous Fleets and Emission Control. *IWI Discussion Paper Series*, 94, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Sonneberg, M.-O., Leyerer, M., Kleinschmidt, A., Knigge, F., Breitner, M.H. (2019a): Autonomous Unmanned Ground Vehicles for Urban Logistics: Optimization of Last Mile Delivery Operations. In: Proceedings of the 52nd Hawai'i International Conference on System Sciences (HICSS) 2019, Grand Wailea, Maui, Hawaii, USA, pp. 1538-1547.

Sonneberg, M.-O., Wei Cao, D., Breitner, M.H. (2016): Social Network Usage of Financial Institutions: A SWOT Analysis based on Sparkasse. *IWI Discussion Paper Series*, 72, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Sonneberg, M.-O., Werth, O., Kohzadi, H., Kraft, M., Neels, B., Breitner, M.H. (2019c): Customer Acceptance of Urban Logistics Delivery Concepts. *IWI Discussion Paper Series*, 91, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Sonneberg, M.-O., Werth, O., Leyerer, M., Wille, W., Jarlik, M., Breitner, M.H. (2019b): An Empirical Study of Customers' Behavioral Intention to Use Ridepooling Services – An Extension of the Technology Acceptance Model. In: Proceedings of the 14th International Conference on Wirtschaftsinformatik (WI) 2019, Siegen, Germany, pp. 83-97.

Spulber, A., Dennis, E.P., Wallace, R., Schultz, M. (2016): *The Impact of New Mobility Services on the Automotive Industry*. Ann Arbor (Michigan, USA): Center for Automotive Research.

Spurlock, C.A., Sears, J., Wong-Parodi, G., Walker, V., Jin, L., et al. (2019): Describing the Users: Understanding Adoption of and Interest in Shared, Electrified, and Automated Transportation in the San Francisco Bay Area. *Transportation Research Part D*, 71, pp. 283-301.

Starship Technologies (2020): The Self-Driving Delivery Robot. Available online https://www.starship.xyz/business, accessed 15.02.2020.

Statista (2019a): Mobilität im Alltag. Available online https://de.statista.com/statistik/studie/id/13604/dokument/mobilitaet-im-alltag-statista-dossier/, accessed 08.02.2020.

Statista (2019b): Urbane Mobilität. Available online https://de.statista.com/statistik/studie/id/68905/dokument/urbane-mobilitaet/, accessed 08.02.2020.

Statista (2019c): Carsharing. Available online https://de.statista.com/statistik/studie/id/9904/dokument/carsharing-statista-dossier/, accessed 08.02.2020.

Stieglitz, M., Sonneberg, M.-O., Breitner, M.H. (2018): TCO-Comparison of Fuel and Electric Powered Taxis: Recommendations for Hannover. *IWI Discussion Paper Series*, 84, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Stillwater, T., Mokhtarian, P.L., Shaheen, S.A. (2009): Carsharing and the Built Environment. Geographic Information System-based Study of one U.S. Operator. *Transportation Research Record*, 2110, pp. 27-34.

Straub, D.W., Burton-Jones, A. (2007): Veni, Vidi, Vici: Breaking the TAM Logjam. *Journal of the Association for Information Systems*, 8(4), article 5.

Straub, D.W., Ang, S. (2011): Rigor and Relevance in IS Research: Redefining the Debate and a Call for Future Research. *Management Information Systems Quarterly*, 35(1), pp. 3-11.

Taniguchi, E. (2014): Concepts of City Logistics for Sustainable and Livable Cities. *Procedia - Social and Behavioral Sciences*, 151, pp. 310-317.

Taniguchi, E., Thompson, R.G., Yamada, T., van Duin, R. (2001): *City Logistics: Network Modelling and Intelligent Transport Systems*. Oxford (United Kingdom): Pergamon.

TfL (2020): Congestion Charge. Available online: https://tfl.gov.uk/modes/driving/con gestion-charge, accessed 15.02.2020.

The Telegraph (2013): Beijing to Impose Odd-Even Car Ban during Heavy Pollution. Available online https://www.telegraph.co.uk/news/worldnews/asia/china/10386738/ Beijing-to-impose-odd-even-car-ban-during-heavy-pollution.html, accessed 28.01.2020.

Thermann, C., Sonneberg, M.-O., Breitner, M.H. (2017): Visualisierung von Verkehrsdaten der Landeshauptstadt Hannover. *IWI Discussion Paper Series*, 81, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Tob-Ogu, A., Kumar, N., Cullen, J., Ballantyne, E. (2018): Sustainability Intervention Mechanisms for Managing Road Freight Transport Externalities: A Systematic Literature Review. *Sustainability*, 10(6), article 1923.

Todd, P., Benbasat, I. (1992): The Use of Information in Decision Making: An Experimental Investigation of the Impact of Computer-Based Decision Aids. *Management Information Systems Quarterly*, 16(3), pp. 373-393.

Toth, P., Vigo, D. (2001): *The Vehicle Routing Problem*. Philadelphia (Pennsylvania, USA): Society for Industrial and Applied Mathematics.

Tricoire, F., Parragh, S.N. (2017): Investing in Logistics Facilities Today to Reduce Routing Emissions Tomorrow. *Transportation Research Part B*, 103, pp. 56-67.

Ullrich, G. (2015): *Automated Guided Vehicle Systems: A Primer with Practical Applications*. Berlin/Heidelberg (Germany): Springer.

United Nations (2014): *World Urbanization Prospects: The 2014 Revision*. New York City (New York, USA): Department of Economic and Social Affairs; United Nations.

UPS Pressroom (2017): UPS Launches Sustainable Deliveries in Frankfurt. Available online https://www.pressroom.ups.com/pressroom/ContentDetailsViewer.page?ConceptType=PressReleases&id=1511885876172-705, accessed 15.02.2020.

Van Audenhove, F.-J., De Jongh, S., Durance, M. (2015): *Urban Logistics: How to Unlock Value from Last Mile Delivery for Cities, Transporters and Retailers*. Brussels (Belgium): Arthur D. Little.

Venkatesh, V., Davis, F.D. (2000): A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. *Management Science*, 46(2), pp. 186-204.

Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D. (2003): User Acceptance of Information Technology: Toward a Unified View. *Management Information Systems Quarterly*, 27(3), pp. 425-478.

Venkatesh, V., Thong, J.Y.L., Xu, X. (2012): Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *Management Information Systems Quarterly*, 36(1), pp. 157-178.

Vinzi, V.E., Trinchera, L., Amato, S. (2010): PLS Path Modeling: From Foundations to Recent Developments and Open Issues for Model Assessment and Improvement. In: Vinzi, V.E., Chin, W.W., Henseler, J., Wang, H. (eds.): Handbook of Partial Least Squares. Berlin/Heidelberg (Germany): Springer, pp. 47-82.

Wang, X., Yuen, K.F., Wang, Y.D., Teo, C.C. (2018): An Innovation Diffusion Perspective of E-Consumers' Initial Adoption of Self-Collection Service via Automated Parcel Station. *International Journal of Logistics Management*, 29(1), pp. 237-260.

Wang, Y., Wang, S., Wang, J., Wei, J., Wang, C. (2020): An Empirical Study of Consumers' Intention to Use Ride-Sharing Services: Using an Extended Technology Acceptance Model. *Transportation*, 47, pp. 397-415.

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. *Management Information Systems Quarterly*, 34(1), pp. 23-38.

Webb, J. (2019): The Future of Transport: Literature Review and Overview. *Economic Analysis and Policy*, 61, pp. 1-6.

Webb, J., Wilson, C., Kularatne, T. (2019): Will People Accept Shared Autonomous Electric Vehicles? A Survey Before and After Receipt of the Costs and Benefits. *Economic Analysis and Policy*, 61, pp. 118-135.

Webster, J., Watson, R.T. (2002): Analyzing the Past to Prepare for the Future: Writing a Literature Review. *Management Information Systems Quarterly*, 26(2), pp.13-23.

Weikl, S., Bogenberger, K. (2013): Relocation Strategies and Algorithms for Free-Floating Car Sharing Systems. *Intelligent Transportation Systems Magazine*, 5(4), pp. 100-111.

Werth, O., Sonneberg M.-O., Leyerer, M., Breitner, M.H. (2020): Behavioral Intention to Use Ridepooling Services - Empirical Insights and Recommendations. *Submitted to* Transportation Research Part A. *Under review*.

Winkenbach, M., Kleindorfer, P.R., Spinler, S. (2016): Enabling Urban Logistics Services at La Poste through Multi-Echelon Location-Routing. *Transportation Science*, 50(2), pp. 520-540.

Wollenburg, J., Hübner, A., Kuhn, H., Trautrims, A. (2018): From Bricks-and-Mortar to Bricks-and-Clicks: Logistics Networks in Omni-Channel Grocery Retailing. *International Journal of Retail & Distribution Management*, 48(4), pp. 415-438.

Xu, J.D., Benbasat, I., Cenfetelli, R.T. (2014): The Nature and Consequences of Trade-Off Transparency in the Context of Recommendation Agents. *Management Information Systems Quarterly*, 38(2), pp. 379-406.

Yang, H.-D., Yoo, Y. (2004): It's All About Attitude: Revisiting the Technology Acceptance Model. *Decision Support Systems*, 38(1), pp. 19-31.

Yu, X., Shen, S. (2019): An Integrated Decomposition and Approximate Dynamic Programming Approach for On-Demand Ride Pooling. *IEEE Transactions on Intelligent Transportation Systems*, (in press, online first).

Zhao, Q., Wang, W., de Souza, R. (2018): A Heterogeneous Fleet Two-Echelon Capacitated Location-Routing Model for Joint Delivery Arising in City Logistics. *International Journal of Production Research*, 56(15), pp. 5062-5080.

Appendices

Appendix A: A Decision Support System for the Optimization of Electric Car Sharing Stations

Authors: Marc-Oliver Sonneberg, Kathrin Kühne, and Michael H. Breitner

Outlet: Proceedings of the 36th International Conference on Information Systems (ICIS) 2015, Fort Worth, Texas, USA.

Link: https://aisel.aisnet.org/icis2015/proceedings/DecisionAnalytics/7/

Abstract: Electric car sharing is a mobility alternative addressing the world's growing need for sustainability and allowing to reduce pollution, traffic congestion, and shortage of parking in cities. The positioning and sizing of car sharing stations are critical success factors for reaching many potential users. This represents a multi-dimensional challenge that requires decision makers to address the conflicting goals of fulfilling demands and maximizing profit. To provide decision support in anticipating optimal locations and to further achieve profitability, an optimization model in accordance to design science research principles is developed. The integration of the model into a decision support system (DSS) enables easy operability by providing a graphical user interface that helps the user import, edit, export, and visualize data. Solutions are illustrated, discussed, and evaluated using San Francisco as an application example. Results demonstrate the applicability of the DSS and indicate that profitable operation of electric car sharing is possible.

Keywords: Electric Car Sharing, Decision Support System, Optimization Model, Design Science Research.

Citation: Sonneberg, M.-O., Kühne, K., Breitner, M.H. (2015): A Decision Support System for the Optimization of Electric Car Sharing Stations. In: Proceedings of the 36th International Conference on Information Systems (ICIS) 2015, Fort Worth, Texas, USA.

Appendix B: Social Network Usage of Financial Institutions: A SWOT Analysis based on Sparkasse

Authors: Marc-Oliver Sonneberg, Danny Wei Cao, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 72, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/IWI_DP_k__72_.pdf

Abstract: In addition to the consequences of the recent financial crisis, traditional financial institutions experience increased competition. New providers offer innovative product solutions and creative ideas of sales approaches and customer retention. In their need to stay competitive, traditional institutions need to find new and entertaining ways of keeping up with their customers. One potential solution lies in social networks, which play an important role in everyday-life of their increasing number of regular users. These networks are typically used to connect with friends, but also to gather and share information about companies or products. The usage of social networks by financial institutions is associated with diverse risks, but at the same time holds great potential to set an organization apart from its competitors. To analyze related chances and risks, a SWOT analysis examines Facebook activities of the Sparkasse. In an internal analysis strengths and weaknesses of the organization are assessed. An external analysis reviews opportunities and threats using the PEST approach. Resulting strategies and recommendations are presented and discussed.

Citation: Sonneberg, M.-O., Wei Cao, D., Breitner, M.H. (2016): Social Network Usage of Financial Institutions: A SWOT Analysis based on Sparkasse. *IWI Discussion Paper Series*, 72, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix C: IKT-basierte Geschäftsmodellinnovationen im Gütertransport: Marktübersicht und Analyse

Authors: Bjarne Neels, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 78, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/IWI_DP_k__78_.pdf

Abstract: In dieser Arbeit wird untersucht, wie weit die Verbreitung IKT-basierter Geschäftsmodelle in der Logistik, speziell im Bereich Gütertransport, vorangeschritten ist. Nach einem Marktüberblick samt kurzer Beschreibung der verschiedenen Konzepte werden diese hinsichtlich verschiedener Aspekte klassifiziert und gegliedert. Anschließend werden sie analysiert und bewertet. Dabei werden alle relevanten Stakeholder mit einbezogen sowie Vor- nach Nachteile gegeneinander abgewogen. Ein Hauptaugenmerk wird hierbei besonders auf die zu erwartenden bzw. resultierenden Veränderungen innerhalb der gesamten Logistikbranche und Lieferkette gesetzt. Ein Fazit samt Ausblick zeigt mögliche Chancen und Entwicklungen für das Feld der IKT-basierten Geschäftsmodelle im Gütertransport.

Keywords: IKT, Geschäftsmodelle, (Urbane) Logistik, Lieferkonzepte, Smart City, App, Umweltschutz.

Citation: Neels, B., Sonneberg, M.-O., Breitner, M.H. (2016): IKT-basierte Geschäftsmodellinnovationen im Gütertransport: Marktübersicht und Analyse. *IWI Discussion Paper Series*, 78, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix D: Analyse innovativer Logistikkonzepte für urbane Paketdienstleister

Authors: Vi Kien Dang, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 80, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/IWI_DP_k__80_.pdf

Abstract: Der stetig wandelnde Prozess im urbanen Gebiet stellt den Paketdienstleistern aufgrund variantenreicher Zustellungsmöglichkeiten vor der großen Herausforderung sich wiederholt veränderten Faktoren anzupassen. Die Anpassungen müssen auf der einen Seite den Anforderungen der Umwelt und des Verkehrs gerecht werden und auf der anderen Seite muss die Zufriedenheit der Kunden gewährleistet werden. In diesem Diskussionspapier sollen Vor- und Nachteile der innovativen Konzepte erfasst werden. Dieses wird basierend auf einer umfassenden qualitativen und quantitativen Analyse geschaffen. Weiterhin soll erörtert werden, inwiefern die neuen Zustellungsmöglichkeiten eine Gefahr für die klassische Lieferkette darstellen. Eine qualifizierte Handlungsempfehlung für die deutsche Paketbranche soll mit den gewonnenen Ergebnissen gegeben werden.

Keywords: (Urbane) Logistik, Innovative Lieferkonzepte, KEP-Dienstleister, Smart City, Umweltschutz, Zustelloptimierung.

Citation: Dang, V.K., Sonneberg, M.-O., Breitner, M.H. (2016): Analyse innovativer Logistikkonzepte für urbane Paketdienstleister. *IWI Discussion Paper Series*, 80, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix E: Visualisierung von Verkehrsdaten der Landeshauptstadt Hannover

Authors: Christoph Thermann, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 81, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/IWI_DP_k__81_.pdf

Abstract: Eine stetig steigende Zahl der Bevölkerung weltweit lebt in Städten. Die Städte sehen sich daher diversen Herausforderungen gegenübergestellt. Neben dem Wohnungsmarkt werden in Zukunft auch aktuelle Verkehrssysteme nicht mehr den Anforderungen der Einwohner gerecht. Dieses Diskussionspapier setzt an der Verkehrsproblematik an und versucht mit Hilfe von Visualisierungstechniken einen Überblick über die aktuelle Verkehrssituation zu geben. Für die Landeshauptstadt Hannover werden frei zugängliche Verkehrsdaten zu mehreren Filmen zusammengeschnitten. Im Resultat werden verkehrliche Hot-Spots der Stadt im Verlauf über die Zeit identifiziert. Mit diesem Wissen sollen Planer und Entscheider unterstützt werden, um alternative Verkehrsführungen zu entwickeln und somit das Verkehrssystem effektiv zu optimieren.

Citation: Thermann, C., Sonneberg, M.-O., Breitner, M.H. (2017): Visualisierung von Verkehrsdaten der Landeshauptstadt Hannover. *IWI Discussion Paper Series*, 81, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix F: Ecological & Profitable Carsharing Business: Emission Limits & Heterogeneous Fleets

Authors: Kathrin Kühne, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: Proceedings of the 25th European Conference on Information Systems (ECIS) 2017, Guimarães, Portugal.

Link: https://aisel.aisnet.org/ecis2017_rp/80/

Abstract: Carsharing is a mobility concept that addresses the world's growing interest in sustainability. It reduces CO_2 emissions, traffic congestion, and noise in cities. Including electric and hybrid vehicles in the carsharing fleet supports these aspects even more. For a station-based carsharing organization (CSO), the distribution and availability of vehicles play a crucial role to satisfy the customers' needs as well as to obtain profits. We developed a tactical optimization model to determine the size and composition of a heterogeneous carsharing fleet while considering different emission limits with time-depended demand profiles. Different propulsion modes and vehicle classes represent the heterogeneity of the fleet. Using the application example of the city of San Francisco, results are presented, discussed, and analyzed. Our benchmarks for two different demand scenarios reveal the strong influence of a preset maximum level of CO_2 emissions on fleet composition and monthly net profit. The optimization model allows CSOs to provide a sustainable and profitable mobility concept; city planners are supported to evaluate influences of CO_2 emission thresholds on CSOs. The model thereby represents a Green IS approach, as it contributes to supporting a society's path towards a low emission and noise-reduced environment in urban areas where carsharing is feasible.

Keywords: Carsharing, Emission Limits, Decision Support, Green IS.

Citation: Kühne, K., Sonneberg, M.-O., Breitner, M.H. (2017): Ecological & Profitable Carsharing Business: Emission Limits & Heterogeneous Fleets. In: Proceedings of the 25th European Conference on Information Systems (ECIS) 2017, Guimarães, Portugal, article 80.

Appendix G: Revenue Management Meets Carsharing: Optimizing the Daily Business

Authors: Justine Broihan, Max Möller, Kathrin Kühne, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: Proceedings of the 27th International Conference on Operations Research (ICOR) 2016, Hamburg, Germany.

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Abstract: Carsharing is a transportation alternative that enables flexible use of a vehicle instead of owning it by paying trip-dependent fees. In recent years, this service denotes a considerable increase of new providers, which face an exponentially growing number of customers worldwide. As a consequence, rising vehicle utilization leads providers to contemplate revenue management elements. When focusing on station-based carsharing concepts, these are typically based on advance reservations. This makes them perfectly suitable for the application of demand-side management approaches. Demand-side management allows providers to optimize their revenues by accepting or rejecting certain trips. We respectively develop an optimization model for revenue management support. Based on an existing model of the hotel business, special consideration is drawn to carsharing related features. For instance, the implementation of a heterogeneously powered fleet allows providers to choose a certain limit of emissions to fulfill local requirements. We implement the mathematical model into the modeling environment GAMS using the solver Couenne. Conducted benchmarks show sensitivities under the variation of different input values, for example risk tolerances. In contrast to the often used first-come first-serve-principle, the results indicate the usefulness of the developed model in optimizing revenues of todays carsharing providers.

Citation: Broihan, J., Möller, M., Kühne, K., Sonneberg, M.-O., Breitner, M.H. (2018): Revenue Management Meets Carsharing: Optimizing the Daily Business. In: Fink, A., Fügenschuh, A., Geiger, M.J. (eds.): Operations Research Proceedings 2016. Basel (Switzerland): Springer International Publishing, pp. 421-427.

Appendix H: Ein Entscheidungsunterstützungssystem zur Tourenplanung am Beispiel eines innovativen Lebensmittel-Lieferkonzeptes

Authors: Sebastian Adam Gebski, Patrick Czerwinski, Max Leyerer, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: Proceedings of the 10th Multikonferenz Wirtschaftsinformatik (MKWI) 2018, Lüneburg, Germany.

Link: http://mkwi2018.leuphana.de/wp-content/uploads/MKWI_247.pdf

Abstract: Die weltweite Urbanisierung führt zu einer erhöhten Nachfrage von innerstädtischen Gütertransporten, wodurch das Verkehrsnetz belastet wird. Moderne Technologie sowie die Nutzung verfügbarer GIS Daten bieten den Anreiz zur Entstehung alternativer und innovativer Lieferkonzepte. Davon betroffen sind ebenfalls urbane Lebensmittel-Lieferdienste, die durch Verwendung verfügbarer mobiler Daten Lieferungen effizienter gestalten können. Dieser Beitrag beschäftigt sich mit einem innovativen Lebensmittel-Lieferkonzept. Hierzu wird ein gemischt ganzzahliges Optimierungsmodell auf Basis eines Vehicle Routing Problems (VRP) mit dem Ziel der dynamischen Zuordnung und Reihenfolgeplanung formuliert. Charakteristisch für die vorliegende Thematik ist die Existenz mehrerer Fahrer in Kombination mit offenen Touren. Die Zuordnung und Planung der Touren wird durch die Implementierung des Optimierungsmodells in ein Entscheidungsunterstützungssystem (EUS) unter Verwendung von Echtzeit Geoinformationsdaten (GIS-Daten) automatisiert und optimiert.

Keywords: City Logistik, Routenplanung, Optimierung, Entscheidungsunterstützungssystem.

Citation: Gebski, S.A., Czerwinski, P., Leyerer, M., Sonneberg, M.-O., Breitner, M.H. (2018): Ein Entscheidungsunterstützungssystem zur Tourenplanung am Beispiel eines innovativen Lebensmittel-Lieferkonzeptes. In: Proceedings of the 10th Multikonferenz Wirtschaftsinformatik (MKWI) 2018, Lüneburg, Germany, pp. 21-32.

Appendix I: TCO-Comparison of Fuel and Electric Powered Taxis: Recommendations for Hannover

Authors: Michael Stieglitz, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 84, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/IWI_DP_k__84_.pdf

Citation: Stieglitz, M., Sonneberg, M.-O., Breitner, M.H. (2018): TCO-Comparison of Fuel and Electric Powered Taxis: Recommendations for Hannover. *IWI Discussion Paper Series*, 84, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix J: Decision Support for Urban E-Grocery Operations

Authors: Max Leyerer, Marc-Oliver Sonneberg, and Michael H. Breitner

Outlet: Proceedings of the 24th Americas Conference on Information Systems (AMCIS) 2018, New Orleans, Louisiana, USA.

Link: https://aisel.aisnet.org/amcis2018/GreenIS/Presentations/5/

Abstract: We discuss an alternative logistics concept for e-grocery operations using an urban network of refrigerated grocery lockers. Regarding the last mile delivery of food and other fast-moving consumer goods, customers either collect their orders by themselves or the products are delivered by means of electric cargo bicycles. To determine the optimal grocery locker locations and both, the routes from the lockers to the consumers as well as the routes from the depot to the grocery lockers, we propose a 2-echelon optimization model minimizing total costs. We present a Location Routing Problem (LRP) in combination with a customized Vehicle Routing Problem (VRP). With our decision support system (DSS), we react to the call of Malhotra et al. (2013) and Gholami et al. (2016) and address the lack of solution-oriented research. We contribute to the Green IS domain by extending the concept of e-grocery with an environmental and social component.

Keywords: Decision Support System, Green IS, Urban Logistics, E-Grocery, Sustainability.

Citation: Leyerer, M., Sonneberg, M.-O., Breitner, M.H. (2018): Decision Support for Urban E-Grocery Operations. In: Proceedings of the 24th Americas Conference on Information Systems (AMCIS) 2018, New Orleans, Louisiana, USA.

Appendix K: Station-based Electric Carsharing: A Decision Support System for Network Generation

Authors: Marc-Oliver Sonneberg and Michael H. Breitner

Outlet: Degirmenci, K., Cerbe, T.M., Pfau, W.E. (eds.) (2020): Electric Vehicles in Shared Fleets: Mobility Management, Business Models and Decision Support Systems. Singapore: World Scientific.

Abstract: Electric carsharing is a mobility alternative addressing the world's growing need for sustainability and allowing to reduce pollution, traffic congestion, and shortage of parking in cities. Since electric vehicles cut down carbon emissions through the use of renewable energy and reduce noise exposure compared to conventionally powered vehicles, they further enhance ecological sustainability within an even sustainable concept. For carsharing services, electric vehicles are a suitable fit for carsharing because typical carsharing trips are comparatively short resulting in uncritical range restrictions for the trips itself. Yet, only station-based approaches can appropriately accommodate charging infrastructures and suitably account for range limitations and charging cycles. The positioning and sizing of carsharing stations are critical success factors for reaching many potential users. This represents a multi-dimensional challenge that requires decision makers to address the conflicting goals of fulfilling demands and maximizing profit. To provide decision support in anticipating optimal locations and to further achieve profitability, an optimization model is developed in this chapter. The integration of the model into a decision support system (DSS) enables easy operability by assisting the user to import, edit, export, and visualize data. Solutions are illustrated, discussed, and evaluated using the city of Portland (OR) as a computational study. Results demonstrate the applicability of the DSS indicating that profitable operation of electric carsharing is possible.

Citation: Not yet available, fulltext attached. Article submitted in 11/2018 and forthcoming. To be cited as: Sonneberg, M.-O., Breitner, M.H. (2020): Station-based Electric Carsharing: A Decision Support System for Network Generation. In: Degirmenci, K., Cerbe, T.M., Pfau, W.E. (eds.): Electric Vehicles in Shared Fleets: Mobility Management, Business Models and Decision Support Systems. Singapore: World Scientific.

1. Introduction

Carsharing is a transportation strategy that offers the usage of vehicles in an organized manner by paying variable trip-dependent fees. After registration at a carsharing organization (CSO), users can utilize any available vehicle of the fleet as long and often required to satisfy their mobility needs. The payment structure differs between the organizations and is usually regulated via varying minute-by-minute fees. Some organizations charge additional fees for mileage or slight monthly basic fees. In any case, carsharing users pay only for trips they actually take and have no unexpected costs such as maintenance, repairs, or continuous costs such as taxes.

Carsharing organizations offer their services in three main variations. The free-floating system enables the user to pick up and drop off a vehicle anywhere within a determined area [Firnkorn and Müller, 2011]. Station-based carsharing services either require the users to do round-trips returning the vehicle to the same station it was picked up at (two-way carsharing), or allow for one-way trips between different stations. To ensure that there is no imbalance within free-floating or one-way carsharing services, relocation techniques are needed [Jorge and Correia, 2013; Shaheen and Cohen, 2013].

Especially, electric carsharing is a mobility alternative addressing the worlds growing need for sustainability and allowing to reduce pollution, traffic congestion, and shortage of parking in cities even more. Since electric vehicles cut down carbon emissions through the use of renewable energy and reduce noise exposure compared to conventionally powered vehicles, they further enhance ecological sustainability within a sustainable concept. For carsharing services, electric vehicles are a suitable fit for carsharing because typical carsharing trips are comparatively short resulting in uncritical range restrictions. Yet, only station-based approaches can appropriately accommodate charging infrastructures and account for range limitations and charging cycles.

For station-based carsharing organizations, the most critical success factor is the challenging task of positioning and sizing carsharing stations to reach the largest possible amount of potential users [Costain *et al.*, 2012]. The accessibility and the distance to users' homes as well as to public transport stations play an important role in attracting potential users [Celsor and Millard-Ball, 2007]. Moreover, different demographic and geographic characteristics such as high population density, shortage of parking, mix of public transportation uses, and the ability to live without a vehicle affect carsharing usage considerably [Celsor and Millard-Ball, 2007; Cohen *et al.*, 2008; Stillwater *et al.*, 2009]. These factors have to be addressed by decision makers when setting up a carsharing network. While trying to allocate the optimal number of stations and vehicles, the organizational objective of profit maximization must be kept in mind. Best practice so far appears to be a trial-and-error concept: stations are randomly opened. If not frequently used, they are closed after a trial period. Otherwise they remain unchanged or the number of vehicles is increased. We suggest supporting the planning process of station and vehicle allocation with a tool that enables decision makers to execute different scenarios. Our decision support system (DSS) allows to import and edit data, set parameters, trigger numerical solving of the underlying model, and visualize optimization results. This enables instant validation, comparison, and assessment of results and scenarios. In addition to its supportive function in implementing carsharing in an economically successful way, our approach helps achieve direct and indirect conservation of resources, and thus leads to increased sustainability. This is exemplarily demonstrated by means of a major city in the US and includes the creation of a specific dataset based on census data and local conditions. The described challenges lead to our research question:

RQ: How can a DSS assist decision makers in planning an optimal carsharing network consisting of electric vehicles?

To answer this question, the remainder is structured as follows: First, the research background is described. In the next section, the optimization model is explained and formally noted. Subsequently, the DSS, which employs the underlying model, is presented. A computational study and benchmarks prove the applicability of the DSS. The next section discusses the presented model, DSS, and corresponding results, followed by critical reflections regarding our approach. We complete our chapter with a conclusion and outlook regarding this field of research.

2. Research Background

Publications on optimization of carsharing networks are manifold, yet they emphasize different aspects. Within our literature review, we analyze different optimization foci for station-based concepts. *Location optimization* refers to the allocation of stations into a carsharing network, which typically represents a strategic approach. *Vehicle optimization* approaches designate the tactical decision level that assess the optimal number of vehicles at each station. In addition to these long- to mid-term perspectives, articles also review *operational optimization* elements such as the service level or vehicle relocation. *DSS* include articles introducing decision support systems regarding various aspects of carsharing. *Electric carsharing* is considered separately from traditional carsharing approaches because both charging infrastructures and charging cycles have to be taken into account. The following Table 1 lists corresponding approaches:

Table 16. Related Work on Carsharing Optimization.

Focus on	Approaches	∑
Location optimization	Awasthi *et al.* [2007], Boyaci *et al.* [2015], Celsor and Millard-Ball [2007], de Almeida Correia and Antunes [2012], Musso *et al.* [2012], Rickenberg *et al.* [2013], Sonneberg *et al.* [2015]	7
Vehicle optimization	Awasthi *et al.* [2007], Boyaci *et al.* [2015], Cepolina and Farina [2012], Di Febbraro *et al.* [2012], El Fassi *et al.* [2012], Kühne *et al.* [2017], Musso *et al.* [2012], Sonneberg *et al.* [2015], Wagner *et al.* [2014]	9
Operational optimization	Alfian *et al.* [2014], Boyaci *et al.* [2015], Broihan *et al.* [2018], de Almeida Correia and Antunes [2012], El Fassi *et al.* [2012], Fan *et al.* [2008], Jorge *et al.* [2014], Kek *et al.* [2006], Kek *et al.* [2009]	9
DSS	El Fassi *et al.* [2012], Kek *et al.* [2009], Rickenberg *et al.* [2013], Sonneberg *et al.* [2015], Wagner *et al.* [2014]	5
Electric carsharing	Boyaci *et al.* [2015], Cepolina and Farina [2012], Khanna and Venters [2013], Kühne *et al.* [2017], Sonneberg *et al.* [2015], Steininger and Bachner [2014]	6

To conclude, the number of articles providing decision support for strategic optimization of location, number, and size of stations as well considering electric vehicles in their optimization approaches is quite lacking. We therefore develop a mathematical model that optimizes an electric carsharing network and maximizes the organization's profit as an objective function. Critical conditions discussed in many of the above named articles are combined in the constraints of this model. We implement this model into a DSS to provide valuable insights for real-life decision makers.

3. Optimization Model

The developed optimization model maximizes the annual profit of a station-based carsharing organization using electric vehicles. In the following, the assumptions, the notation, the mathematical model, and its description are presented.

The object in consideration is the classic two-way carsharing scheme. Every vehicle has its designated parking lot, meaning vehicles have to be picked up and returned to the same location. The objective of the optimization model explicitly concerns strategic and tactical planning of a carsharing network; operational aspects are not considered. Stochastic and normal distributed demand points for carsharing exist. These demand points are allocated within the investigation area and are provided on a punctual basis by geographic coordinates. The demand has to be fulfilled completely to reach the maximum customer satisfaction. Possible supply points in the form of carsharing stations are spread over the specific investigation area to satisfy the demand. These points are also characterized by exact geographic coordinates. For each of the potential stations, a maximum limit of parking lots is defined to reflect local land-use conditions in the surroundings of the respective station. Annual leasing costs for vehicles, parking lots, and stations are introduced. These contain all incidental expenses and explicitly not only the initial costs. The subject matter are electric vehicles, which are completely battery powered and require trip-dependent charging cycles. Two different options of the charging process can be simulated for the otherwise homogenous fleet. Firstly, regular charging can be used through the conventional local grid-connection. As an alternative, more efficient fast chargers via special 50 kW DC charging elements can be chosen. Depending on the option, different charging times and adjusted leasing costs are being considered. The implementation of electric vehicles into the carsharing fleet requires additional parameters. Charging condition and influencing elements such as range, average speed, and power consumption are therefore considered. The power consumption depends on the duration of a trip and the distance driven. Hence, these are integrated as trip-dependent parameters and modelled stochastically by a normal distribution. A maximum number of possible trips per day results from the choice of trip-dependent parameters and the corresponding fast or regular charging times. The charging time is linearly correlated to the travel time. This means that one hour of travel time is always associated with a fixed time to recharge the battery. Variations in demand typically do not represent a part of a strategic, i.e., a long-term problem. To grant decision makers a certain degree of variation, the suggested model allows the demand to be varied throughout the week by determining peak and off-peak weekdays. An additional variation of the demand (e.g., throughout the day or year) is not expected to add further value to the strategic allocation of stations and tactical assignment of vehicles and should rather be included in operative approaches.

The following Table 2 presents the underlying notation for the subsequent mathematical model.

Table 17. Underlying Notation including Sets, Parameters, and Decision Variables.

Element	Description	Unit / Range
cc^f	Leasing cost of a fast charger	USD p.a.
cc^r	Leasing cost of a regular charger	USD p.a.
cp	Leasing cost of a parking lot	USD p.a.
cs	Leasing cost of a station	USD p.a.
cv	Leasing cost of a vehicle	USD p.a.
d_{ij}	Distance between station i and station j	Km
D	Maximum distance between station i and station j	Km
e	Average energy consumption	Kwh/km
i	Set of potential station locations	(1, … , I)
j	Set of demand locations	(1, … , J)
L_i	Maximum number of possible parking lots at station i	#
L^f	Maximum number of possible fast chargers per station	#
m	Expected duration of a rent	Min
n_j	Normal distributed demand	Rents/week
N	Demand of busiest interval	Rents/day
p	Price per electricity	USD/kwh
r	Revenue for renting	USD/min
t	Expected trip distance driven	Km
x^f	Possible trips of fast charged vehicle per day	#
x^r	Possible trips of regular charged vehicle per day	#
v_i^f	Number of vehicles fast charged at station i	#
v_i^r	Number of vehicles regular charged at station i	#
y_i	1, if station i is built; 0, else	Binary
z_i	1, if demand location j is served by station i; 0, else	Binary

$$Max.F = \sum_{j=1}^{J} d_j * (\mathrm{m} * r) - \sum_{j=1}^{J} d_j * (t * e * p) - \sum_{i=1}^{I} \left(v_i^r * \left(cv + cp + cc^r \right) + v_i^f * \left(cv + cp + cc^f \right) + y_i * cs \right) \tag{1}$$

$$\sum_{i=1}^{I} z_{ij} \geq 1 \qquad \forall\, j \tag{2}$$

$$y_i \geq z_{ij} \qquad \forall\ i \ and \ j \tag{3}$$

$$v_i^r * x^r + v_i^f * x^f \geq \sum_{j=1}^{J} \left(dmax_j * z_{ij} \right) \qquad \forall\ i \tag{4}$$

$$v_i^r + v_i^f \leq maxl_i \qquad \forall\ i \tag{5}$$

$$v_i^f \leq maxlf \qquad \forall\ i \tag{6}$$

$$dist_{ij} * z_{ij} \leq maxdist \qquad \forall\, i \, and \ j \tag{7}$$

$$y_i \in \{0,1\} \qquad \forall\ i \tag{8}$$

$$z_{ij} \in \{0,1\} \qquad \forall\ i \, and \ j \tag{9}$$

$$v_i^r,\ v_i^f \geq 0 \qquad \forall\ i \tag{10}$$

The objective function (1) maximizes the profit of a carsharing organization by calculating the revenue and subtracting the resulting variable and the annual leasing costs. Demand points can be served by one or more stations to split the expected demand (2). Constraint (3) ensures that every demand point can only be assigned to a station that is actually built. The existing demand has to be satisfied completely in compliance with corresponding charging times (4). The factors x^f and x^r are used to calculate the possible number of trips per day, taking into account the average speed, trip duration, and corresponding charging times. Every station has a limited number of parking spaces for vehicles to consider local parking conditions at that station (5). To prevent a grid overload, constraint (6) sets a maximum amount of fast charging infrastructures at all stations. Constraint (7) ensures that a maximum distance between a demand point and an associated station is not exceeded. Equations (8), (9), and (10) set the specific value range of the decision variables of the model.

4. Decision Support System

In addition to the developed mathematical model that optimizes the network of carsharing stations, a DSS is constructed. The DSS is a Java-based web application that enables decision support for the optimal placement and size of carsharing stations. It integrates the optimization model and additional applications into one system. As principles of usability and comprehensible visual appearance are applied, it enables decision makers to easily run their own case studies. After the desired datasets are developed and imported as well as parameters selected, the DSS solves the equations of the underlying model and displays the appropriate results in an illustrative way. As a result, it contributes to less pollution and a more sustainable environment. The basic requirement for the optimization is the software GAMS, a modeling system for mathematical programming. Further software used to develop the DSS is Eclipse Luna with the actual Java Development Kit and Notepad++.

A dataset for the respective investigation area needs to be developed by decision makers as external input in the form of an .xml file. The DSS provides the option to both load and edit data, such as potential carsharing stations. Furthermore, parameters of the mathematical model can be set and varied by the user to simulate different scenarios. When starting the optimization, an input data file including the values of parameters is written. GAMS and the connected solver IBM ILOG CPLEX then calculate the optimal solution of the mathematical model. GAMS automatically generates a solution files which are used to display the optimization process and the results. For an additional graphical visualization, the resulting carsharing network can be exported to an .html file via Google Maps API. Figure 1 presents the graphical user interface for parameter setting of the DSS.

Fig. 1. Graphical User Interface of the DSS.

5. Computational Study

In order to evaluate the developed DSS, we provide a computational study together with benchmarks. The success of a carsharing organization depends on different demographic and geographic characteristics such as high population density, parking pressures, mix of transportation means, and the ability to live without a vehicle [Celsor and Millard-Ball, 2007; Cohen *et al.*, 2008; Stillwater *et al.*, 2009]. For this purpose, we chose the city of Portland (OR), which satisfies all required characteristics and already successfully accommodates carsharing networks. Portland is the economic center and largest city of the state of Oregon close to the Canadian border and has an appropriate population of about 580,000 inhabitants. Within the mostly rectangular oriented streets, a well-developed public transport system covers the complete city consisting of trams, buses, street cars, and an aerial passenger line. Further, the city disposes a dense charging infrastructure network for electric vehicles and permits electric vehicles to park and charge free of charge. Together with a dense bicycle lane network, Portland can be characterized as a sustainable city.

For our evaluation, we set the demand locations analogous to the subdivision of blocks according to the U.S. Census Bureau. With the exception of sparsely populated blocks (e.g., parks or islands) which are not considered, Portland is divided into 436 blocks. Each block is characterized by a particular demand location in its center of settlement indicated by geographical coordinates. A total of 1,300 potential supply points are distributed consistently over the whole investigation area and, likewise, with precise geographical positions. Due to the proven correlation between public transport and carsharing, possible stations are set close to access points of public transportation [Celsor and Millard-Ball, 2007].

The estimation of demand levels for carsharing is summarized in a literature review published by Jorge and Correia [2013]. As stated in recent studies and investigations, some generalizations about carsharing participants are feasible. Correspondingly, we base our demand estimation on several population characteristics. By far, the highest share of people using carsharing services are those between 22 and 39 years old [Andrew and Douma, 2006; Burkhardt and Millard-Ball, 2006; Firnkorn and Müller, 2012; Morency *et al.*, 2011]. A typical carsharer is above-average educated (at least to bachelor degree level) and often lives in small non-family households with a maximum of two people [Andrew and Douma, 2006; Burkhardt and Millard-Ball, 2006; Habib *et al.*, 2012; Stillwater *et al.*, 2009]. Equipped with less than one vehicle per household, a carsharer generally lives in an apartment building with more than five housing units [Andrew and Douma, 2006; Burkhardt and Millard-Ball 2006; Firnkorn and Müller, 2012; Habib *et al.*, 2012]. Several other criteria such as typical income levels are not considered due to ambiguous information. Based on these findings, we determined a group of potential carsharing users for each block that complies with all of these requirements. We used the latest forecasted data published by the U.S. Census, available on their homepage. Based on that data, we calculated the demand per block as input for the mathematical model as follows. We weight five in literature proven population criteria, named age, education, housing unit, available vehicles, and household type to allocate the number of potential carsharing users. In accordance with Burkhardt and Millard-Ball [2006], Habib *et al.* [2012], and Morency *et al.* [2011], we then assume an average trip frequency of three trips per user per month. As not every potential user actually participates in carsharing, the absolute number of carsharers is much lower. Different surveys suggest inconsistent values between 1% and 10%, therefore we choose a percentage of 5% within this study. The potential station locations within the optimization model are characterized by a particular limit of parking lots. These numbers result from local conditions such as bilateral parking, parallel or transverse parking, on-street, or off-street parking. Table 3 summarizes the initial values used for the required parameters to execute the DSS.

Table 18. Input Values.

Parameter	Value	Parameter	Value
Vehicle [USD p.a.]	12,000	Charging time reg [min]	480
Parking lot [USD p.a.]	1,200	Charging time fast [min]	30
Station [USD p.a.]	600	Max. fast chargers [#]	2
Regular charger [USD p.a.]	100	Max. distance [km]	0.75
Fast charger [USD p.a.]	6,000	Max. range [km]	150
Std. dev. of demand	2	Av. speed [km / h]	25
Av. trip duration [min]	180	Monday	0.1
Std. dev. trip duration [min]	60	Tuesday	0.1
Av. Trip distance [km]	35	Wednesday	0.1
Std. dev. trip distance [km]	20	Thursday	0.15
Revenue [USD / min]	0.15	Friday	0.15
Consumption [kWh / km]	0.15	Saturday	0.2
Price [USD / kWh]	0.1	Sunday	0.2

We chose the distinct values based on the following explanations. The first values refer to the various annual leasing costs. The leasing costs for a vehicle include initial and running costs for purchase, battery, insurance, taxes, maintenance, cleaning, administration, depreciation, and amortization over the year. Leasing costs for parking lots correspond to rental charges of the ground. Cost for maintenance and cleaning of a parking lot as well as parking signage are incurred within the costs for a station. The leasing costs for a regular charging infrastructure unit contain the establishment and maintenance of a power line to the grid of the infrastructure. The annual leasing cost for a unit of fast charging infrastructures include the installation, connection, and maintenance of high voltage power lines to the power mains. The discussed demand levels per block serve as mean value within a normal distribution. Likewise, the trip duration and the trip distance are normal distributed. The mean values are chosen based on findings of recent studies. The distance driven per trip varies between 20 and 60 kilometers [Duncan, 2011; Morency *et al.*, 2011]. The whole duration of a trip, including driving and parking times, varies between half an hour and four hours [Alfian *et al.*, 2014]. To limit the solution, thresholds are considered. The threshold of a maximum number of fast charging infrastructures restricts the solution regarding the capital expenditure and the securing of network coverage. One of the strongest influence factors on the solution is the maximum distance between demand and station location. Various surveys and observations deviate between 250 meters and two kilometers, others state a maximum walking distance of 10.75 minutes [Morency *et al.*, 2008; Costain *et al.*, 2012; Celsor and Millard-Ball, 2007]. The revenue per minute includes both driving and parking times. The energy consumption per kilowatt hour of the vehicle is computed per kilometer. Besides these adjustments, some additional parameters related to the charging cycles were chosen. The maximum range of the vehicle is set to a usual range of the average electric vehicle. The average speed is set to a typical city locomotion of 25 km/h in accordance to Kriston *et al.* [2010]. Recharging of an empty battery with a regular charging infrastructure via a standard outlet such as a charging station connected to the grid takes about eight hours. The 50 kW DC high voltage fast charging infrastructure significantly increases the process. We chose a value of 30 minutes to recharge a battery based on the specifications of different manufacturers. Literature states that the demand level varies between weekdays and weekends [Millard-Ball *et al.*, 2005]. Values are chosen to simulate that the usage of carsharing rises slightly but constantly throughout the week and achieves its maximum at the weekend [Costain *et al.*, 2012; Alfian *et al.*, 2014].

The following calculations were conducted on a standard laptop (Intel Core i7 2.5 GHz CPU with 16 GB RAM) using the optimization tool GAMS 24.1.3 with the solver CPLEX 12.5.1 and a set optimization gap of 10% or a maximum computing time of 6,000 seconds.

In this example, the carsharing organization is able to achieve a profit of 54,660 US$ per year. In total, 39 stations should be deployed with a carsharing fleet of 42 electric vehicles. Every vehicle has its specific parking lot at each station, with 15 of them having fast charging infrastructure and 27 regular charging infrastructure. The served area is widespread, since the city is not densely populated. In order to avoid an information overload in the illustration, markers for the demand are not directly shown. However, when users click on an area close to a station marker, the demand locations and their respective properties are displayed. Figure 2 visualizes the resulting network for the city of Portland.

Fig. 2. Visualization of Results for the City of Portland (OR).

6. Benchmarks

In general, the optimal values to maximize profit depend on the settings and parameters used. Different alternatives can be calculated and visualized to allow decision support for the process of finding the solution that best meets the actual budgetary or strategic goals of the carsharing organization. Therefore, the following Table 4 section varies ceteris paribus certain parameters providing the influence of crucial input factors. These parameters are the maximum distance which is varied between 0.75 and 2 km and the average trip duration demonstrated in two profiles (two vs three hours). Each subsection of the table is divided into profit, total number of stations, number of vehicles with fast charging infrastructure (v_i^f), and number of vehicles with regular charging infrastructure (v_i^r).

Table 19. Benchmark Results.

Av. trip duration 2 hours				Av. trip duration 3 hours		
0,75	1	2	km	0,75	1	2
-74.960	80.714	203.722	Profit (US$)	54.660	194.204	309.447
39	28	15	Stations (#)	39	27	17
11	10	13	v_i^f (#)	15	17	19
29	19	7	v_i^r (#)	27	14	4

As visible in Table 4, the following findings are apparent. With increasing maximum distance, the annual profit increases as more customers are attracted to use carsharing. The higher the maximum distance, the less stations and vehicles are required to satisfy the demand.

Apparently, the longer the trip-duration, the higher the profit. With longer trip-durations (3 hours in contrast to 2 hours), more vehicles are needed to satisfy the demand. With rising trip-durations, regular charged vehicles are supplemented by fast charging vehicles to allow for shorter charging cycles and resulting less idle times. When varying the percentages of the target group, in other words the demand, the results follow the stated trends. The higher the target group, the more vehicles and in consequence also more stations are necessary to satisfy the demand, and vice versa. Since vehicles with fast charging infrastructure are able to serve more users, the number increases with a higher focus group even though they are more expensive, but in total it is more profitable for the carsharing organization.

7. Discussion

In order to provide decision support for the optimization of the location and size of electric carsharing stations, we base our optimization model on existing operations research models and integrate it into a DSS. In doing so, we provide for additional usability by creating an intuitive interface for managers, planners, and decision-makers. We further explain the creation of the required dataset using the application example of Portland. Respective benchmarks complete our demonstration and show feasibility of model and DSS.

The model and the DSS allow users to easily integrate the characteristics of a city to solve the complex problem of determining optimal locations and sizes of carsharing stations. It enables carsharing organizations to plan and implement carsharing within a new city in one big step to demonstrate extensive market presence from the beginning as compared to common trial-and-error concepts. Numerous parameters such as electric properties of vehicles or various leasing costs are included to help fine-tune the strategic and tactical optimization. This feature eases the inclusion of different scenarios and accounts for alternative vehicles, such as subcompact or mid-range electric vehicles, or the use of different charging infrastructures as is shown in our examples. It also enables decision makers to perform sensitivity analyses to evaluate the effects of different input parameters and thus helps to ascertain a profitable solution for their individual case. In order to achieve low computing times, a gap can be set, so that a result is found quickly. With additional computing time, further improvements of the gap are possible. However, since the model addresses strategic and tactical planning as compared to operative control, for example, computing time does not represent a critical aspect. This also applies to other operative factors, such as demand variations throughout the day or year (e.g., peaks due to events), cleaning cycles, or vehicle inspection, which are not considered. The applicability and feasibility of the developed DSS were tested using the city of Portland as an example. The city fulfills the required prerequisites to theoretically allow for profitable carsharing and has a proven track record of successful carsharing implementation. The benchmarks suggest that the approach of electric carsharing can be profitably realized. As expected, in addition to the optimal allocation of stations and vehicles throughout the city, the demand plays an important role in our results and is the key to a successful implementation. Overall results indicate that our DSS and the underlying optimization model can help decision makers to evaluate the profitability of their respective case. Results further emphasize the importance of accurate data, specifically regarding demographics, to ensure a sound dataset allowing for realistic demand estimations.

Since carsharing, and especially electric carsharing, aim for a clean environment with state-of-the-art technology, the introduced model also contributes to enhanced ecological, social, and economic sustainability. Moreover, the model and DSS allow carsharing organizations to plan their station arrangements in a time-saving, yet optimal manner.

8. Critical Reflections

Our model and DSS create a precise recommendation of station allocation throughout a city. However, certain limitations and possible enhancements need to be considered. Theoretically, the applicability of the model is not limited, i.e., it can be used for any city worldwide that fulfills the discussed conditions with regard to geographic and demographic characteristics. The evaluation of the model and its applicability was limited to the city of Portland in the course of this chapter. Further tests for other cities with different structure or population are required to ensure transferability and generalizability.

Our model is based on many simplifications and assumptions. A realistic estimation of the demand is crucial to success. We consolidated a number of articles and created an image of the typical electric carsharing user. In combination with census data, a reasonable first demand estimation can be calculated without financial impact. However, the demand depends on many different variables, such as the price of carsharing, structure of the city, and public transport, but also on the competitive market situation. Demographic data for the considered area allows for a first estimation of the demand. Additional criteria can help further refine the group of potential users. Our model does not explicitly consider competition, yet a variation in the percentage of the focus group can indirectly adjust the demand to lower values when competitors are present. To underline their business case we would still encourage decision makers to gain additional data, for example, from questionnaires or interviews in the corresponding areas.

Not only are further parameters such as average trip duration, speed, and distance related to the expected demand, they also strongly depend on individual characteristics of the respective city, including density of traffic and expansion of the local public transport. Although the model facilitates station allocation, it cannot replace a sound evaluation by decision makers. Also, we only considered deterministic data and not a stochastic distribution. In any case, the application example shows that the modelling of the demand is adequate by using literature to identify a potential user group and thereby distribute the potential demand. Further, the implementation of additional multi-mobility constraints, i.e., emphasizing the importance of stations near public transportation and especially the central station, might improve the model. We only consider the demand of the habitual abode of potential users and not the demand around business areas or public transport stations due to a lack of data and research in this realm. In addition, only an average price for all carsharing users is assumed. In future amendments of the model, the price elasticity of demand should be considered as it has an influence on the demand and the profit of a carsharing organization. The model could also be expanded by creating timeframes throughout the day and the week and combining them with demand-related prices. These suggestions already considerably overlap with operational approaches and fine-tune our strategic and tactical model rather than significantly changing it. Since the demand for carsharing in a one-way and free-floating mode is increasing [Ciari *et al.*, 2014], the two-way service suggested in our model is not optimal to reach highest demands. Due to the requirement for charging infrastructures for electric vehicles, the free-floating service is not a suitable approach though. Even though possible, one-way trips generate significantly more costs by requiring additional charging infrastructures at each station and staff for the relocation. Thus, the proposed two-way model represents an effective way of implementing electric carsharing strategically using today’s technology.

9. Conclusions and Outlook

Increased environmental awareness and possible cost savings are making people reconsider their current modes of transportation as well as the need for personal vehicle ownership. Carsharing, and especially electric carsharing, represents an attractive alternative. To successfully implement carsharing within a city, solutions to satisfy the demand for station locations, their sizes, and an optimal number of vehicles have to be found.

In this chapter, we introduced a model to provide decision support for the complex task of planning the optimal locations and sizes of electric carsharing stations. The integration of the model into a DSS enhances the applicability and usability of our approach. The DSS provides a user-friendly interface, allows data import, and triggers the optimization and visualization of results. The DSS and the underlying model were evaluated and demonstrated using the example of the city of Portland (OR). The benchmarks reveal the influence of crucial parameters to the network establishment. Although certain limitations have been identified, the applicability and usefulness of the optimization model and the DSS were evaluated and shown. Especially when discussing the model, implications and recommendations for additional research can be derived.

To conclude, we emphasize that the potential of electric carsharing is considerable, with regard to both sustainability and profitable installation. The developed model thereby supports the strategic and tactical planning phase by providing decision support. Along with further enhancements, our work contributes to support the society's path towards a low emission and noise-reduced environment.

References

Alfian, G., Rhee, J., and Yoon, B. (2014). A simulation tool for prioritizing product-service system (PSS) models in a carsharing service, *CAIE*, 70, pp. 59-73.

Andrew, J., and Douma, F. (2006). Developing a model for carsharing potential in Twin Cities neighbourhoods, in *Proc. 85th Transportation Research Board*, TRB, pp. 22-26.

Awasthi, A., Breuil, D., Chauhan, S. S., Parent, M., and Reveillere, T. (2007). A multicriteria decision making approach for carsharing stations selection, *J. Dec. Sys.*, 16:1, pp. 57-78.

Boyaci, B., Zografos, K. G., and Geroliminis, N. (2015). An optimization framework for the development of efficient one-way car-sharing systems, *EJOR*, 240:3, pp. 718-733.

Broihan, J., Möller, M., Kühne, K., Sonneberg, M.-O., and Breitner, M.H. (2018). Revenue Management meets Carsharing: Optimizing the Daily Business, *Proc. Operations Research Conf.*, OR, pp. 421-427.

Burkhardt, J. E., and Millard-Ball, A. (2006). Who is attracted to carsharing?, *J. of the TRB*, 1986, pp. 98-105.

Ciari, F., Bock, B., and Balmer, M. (2014). Modeling Station-based and Free-floating Carsharing Demand: A Test Case Study for Berlin, Germany, *Proc. 93th Transportation Research Board*, TRB, 13 p.

Celsor, C., and Millard-Ball, A. (2007). Where does carsharing work?: Using geographic information systems to assess market potential, *J. of the TRB*, 1992, pp. 61-69.

Cepolina, E. M., and Farina, A. (2012). A new shared vehicle system for urban areas, *Transportation Research Part C*, 21:1, pp. 230-243.

Cohen, A. P., Shaheen, S., and McKenzie, R. (2008). Carsharing: A guide for local planners, Institute of Transportation Studies, University of California Berkeley, Working Paper.

Costain, C., Ardron, C., and Habib, K. N. (2012). Synopsis of users' behaviour of a carsharing program: A case study in Toronto, *Transportation Research Part A*, 46:3, pp. 421-434.

de Almeida Correia, G. H., and Antunes, A. P. (2012). Optimization approach to depot location and trip selection in one-way carsharing systems, *Transportation Research Part E*, 48:1, pp. 233-247.

Di Febbraro, A., Sacco, N., and Saeednia, M. (2012). One-way carsharing: Solving the relocation problem, *J. of the TRB*, 2319, pp. 113-120.

Duncan, M. (2011). The cost saving potential of carsharing in a US context, *Transportation*, 38:2, pp. 363-382.

El Fassi, A., Awasthi, A., and Viviani, M. (2012). Evaluation of carsharing network's growth strategies through discrete event simulation, *Expert Systems with Applications*, 39:8, pp. 6692-6705.

Fan, W. D., Machemehl, R. B., and Lownes, N. E. (2008). Carsharing: Dynamic decision-making problem for vehicle allocation, *J. of the TRB*, 2063, pp. 97-104.

Firnkorn, J., and Müller, M. (2011). What will be the environmental effects of new free-floating car-sharing systems? The case of car2go in Ulm, *Ecological Economics*, 70:8, pp. 1519-1528.

Habib, K. M. N., Morency, C., Islam, M. T., and Grasset, V. (2012). Modelling users' behaviour of a carsharing program: Application of a joint hazard and zero inflated dynamic ordered probability model, *Transportation Research Part A*, 46:2, pp. 241-254.

Jorge, D., and Correia, G. (2013). Carsharing systems demand estimation and defined operations: a literature review, *EJTIR*, 13:3, pp. 201-220.

Jorge, D., Correia, G. H., and Barnhart, C. (2014). Comparing optimal relocation operations with simulated relocation policies in one-way carsharing systems, *IEEE ITS*, 15:4, pp. 1667-1675.

Kek, A. G., Cheu, R. L., and Chor, M. L. (2006). Relocation simulation model for multiple-station shared-use vehicle systems, *J. of the TRB*, 1986, pp. 81-88.

Kek, A. G., Cheu, R. L., Meng, Q., and Fung, C. H. (2009). A decision support system for vehicle relocation operations in carsharing systems, *Transportation Research Part E*, 45:1, pp. 149-158.

Khanna, A., and Venters, W. (2013). The Role Of Intermediaries In Designing Information Infrastructures In Strategic Niches: The Case Of A Sustainable Mobility Infrastructure Experiment In Berlin, in *Proc. 21st Eur. Conf. Inf. Sys.*, ECIS, 12 p.

Kriston, A., Szabó, T., and Inzelt, G. (2010). The marriage of car sharing and hydrogen economy: A possible solution to the main problems of urban living, *Int. J. of Hydrogen Energy*, 35:23, pp. 12697-12708.

Kühne, K., Sonneberg, M.-O., and Breitner, M.H. (2017). Ecological & Profitable Carsharing Business: Emission Limits & Heterogeneous Fleets, *Proc. 25th Eur. Conf. Inf. Sys.*, ECIS, pp. 1232-1247.

Millard-Ball, A., Murray, G., Burkhardt, J., and ter Schure, J. (2005). Car-Sharing: Where and How it Succeeds, TCRP Report 108: The National Academies Press.

Morency, C., Trépanier, M., and Agard, B. (2011). Typology of carsharing members, in *Proc. 90th Transportation Research Board*, TRB, 14 p.

Musso, A., Corazza, M. V., and Tozzi, M. (2012). Car Sharing in Rome: a Case Study to Support Sustainable Mobility, *Procedia – Social and Behavioral Sciences*, 48, pp. 3482-3491.

Rickenberg, T.A., Gebhardt, A., and Breitner, M.H. (2013). A Decision Support System for the Optimization of Car Sharing Stations, *Proc. 21st Eur. Conf. Inf. Sys.*, ECIS, 12 p.

Shaheen, S., and Cohen, A. P. (2013). Carsharing and personal vehicle services: worldwide market developments and emerging trends, *Int. J. of Sustainable Transportation*, 7:1, pp. 5-34.

Sonneberg, M.-O., Kühne, K., & Breitner, M.H. (2015). A decision support system for the optimization of electric car sharing stations, *Proc. 36th Int. Conf. Inf. Sys.*, ICIS, 16 p.

Steininger, K. W., and Bachner, G. (2014). Extending car-sharing to serve commuters: An implementation in Austria, *Ecological Economics*, 101, pp. 64-66.

Stillwater, T., Mokhtarian, P. L., and Shaheen, S. A. (2009). Carsharing and the built environment. Geographic Information System–Based Study of One U.S. Operator, *J. of the TRB*, 2110, pp. 27-34.

Wagner, S., Brandt, T., Kleinknecht, M., and Neumann, D. (2014). In Free-Float: How Decision Analytics Paves the Way for the Carsharing Revolution, *Proc. 35th Int. Conf. Inf. Sys*, ICIS, 16 p.

Appendix L: Autonomous Unmanned Ground Vehicles for Urban Logistics: Optimization of Last Mile Delivery Operations

Authors: Marc-Oliver Sonneberg, Max Leyerer, Agathe Kleinschmidt, Florian Knigge, and Michael H. Breitner

Outlet: Proceedings of the 52nd Hawai'i International Conference on System Sciences (HICSS) 2019, Grand Wailea, Maui, Hawaii, USA.

Link: https://doi.org/10.24251/HICSS.2019.186

Abstract: In an era dominated by ongoing urbanization and rising e-commerce, the efficient delivery of goods within cities becomes a major challenge. As a new element of urban logistics, we discuss the potential of autonomous unmanned ground vehicles (AUGV) regarding the last mile delivery of shipments to customers. We propose an optimization model to minimize the delivery costs of urban shipments using AUGV. Simultaneously, best locations from a set of existing stations are selected for AUGV positioning and optimal route determination. With our developed Location Routing Problem, we provide decision support for parcel service providers, city authorities, and other relevant decision makers. Regarding the Green Information Systems domain, we tackle the lack of solution-oriented research addressing a more sustainable and locally emission free supply of goods within urban areas.

Citation: Sonneberg, M.-O., Leyerer, M., Kleinschmidt, A., Knigge, F., Breitner, M.H. (2019): Autonomous Unmanned Ground Vehicles for Urban Logistics: Optimization of Last Mile Delivery Operations. In: Proceedings of the 52nd Hawai'i International Conference on System Sciences (HICSS) 2019, Grand Wailea, Maui, Hawaii, USA, pp. 1538-1547.

Appendix M: An Empirical Study of Customers' Behavioral Intention to Use Ridepooling Services – An Extension of the Technology Acceptance Model

Authors: Marc-Oliver Sonneberg, Oliver Werth, Max Leyerer, Wiebke Wille, Marvin Jarlik, and Michael H. Breitner

Outlet: Proceedings of the 14th International Conference on Wirtschaftsinformatik (WI) 2019, Siegen, Germany.

Link: https://aisel.aisnet.org/wi2019/track02/papers/1/

Abstract: Shared mobility services for passenger transportation become increasingly popular all over the world. As services like carsharing are already well-established and well-accepted, ridepooling services are at their early stage and currently within first implementations. The most critical success factor of such services is the customer acceptance. We investigate the acceptance of 115 German questionnaire respondents using and extending the Technology Acceptance Model. Results indicate that the success factors of the developed model serve as useful predictors of the behavioral intention to use ridepooling services. Perceived compatibility was identified to have the strongest impact whereas perceived ease of use and perceived safety are not relevant for accepting ridepooling services. Based on these findings, our paper provides management implications and recommendations to improve acceptance and success of ridepooling services in Germany.

Keywords: Ridepooling, Passenger Transportation, Urban Mobility, Technology Acceptance Model, Structural Equation Modeling.

Citation: Sonneberg, M.-O., Werth, O., Leyerer, M., Wille, W., Jarlik, M., Breitner, M.H. (2019): An Empirical Study of Customers' Behavioral Intention to Use Ridepooling Services – An Extension of the Technology Acceptance Model. In: Proceedings of the 14th International Conference on Wirtschaftsinformatik (WI) 2019, Siegen, Germany, pp. 83-97.

Appendix N: Analysis of Augmented Reality Applications within the German Automotive Industry

Authors: Philip Blacha, Marvin Kraft, Marc-Oliver Sonneberg, Maximilian Heumann, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 88, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/IWI_DP_k__88_.pdf

Abstract: Augmented Reality (AR) is a modern technology that offers new opportunities along the entire value chain of the automotive industry. In this paper, the potential of AR in different use cases of the German automotive industry is presented. Furthermore, strengths and weaknesses of the technology are discussed and the influence of this technology on the strategic perspective of the German automotive industry is investigated. The results of the investigation reveal that AR can make a significant contribution to increased efficiency, cost savings and process optimization. The available hardware, however, still shows some weaknesses in its current state of development, which can be remedied by research. The mature technology holds great opportunities for the German automotive industry to exploit opportunities arising from the development of the corporate environment and to avert threats.

Keywords: Augmented Reality, German Automotive Industry, SWOT Analysis, PEST Analysis.

Citation: Blacha, P., Kraft, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H. (2019): Analysis of Augmented Reality Applications within the German Automotive Industry. *IWI Discussion Paper Series*, 88, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix O: Customer Acceptance of Urban Logistics Delivery Concepts

Authors: Marc-Oliver Sonneberg, Oliver Werth, Human Kohzadi, Marvin Kraft, Bjarne Neels, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 91, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/K_DP_91_Akzeptanz_Logistikkonzepte.pdf

Abstract: Urbanization as a global trend leads to a rapid increase of urban freight transports in cities, particularly on the last mile. Additional trends such as the increasing importance of electronic commerce and the associated growth in business-to-customer deliveries aggravate the situation even more. In view of the resulting challenges such as traffic congestion and air pollution, especially public authorities are obliged to react. An implementation of optimized urban logistics concepts is therefore necessary in order to improve the efficiency and sustainability of delivery processes on the last mile. The final realization of these concepts requires the support of various stakeholders. Hence, the purpose of this discussion paper is to investigate potential acceptance factors for urban logistics concepts from an end customer perspective. In doing so, the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model was used and extended. By means of an online survey, the impacts of the different constructs on the behavioral intention (BI) and usage behavior (UB) of customers towards 14 different urban logistics concepts were examined in Germany. The results indicated that performance expectancy (PE) is the most significant antecedent of end customers BI. Further, it was pointed out that the actual UB of customers to utilize urban logistics concepts was exclusively positively influenced by habit (HT) of customer towards urban logistics concepts. With respect to customers UB, HT revealed a strong significance for thirteen of the included concepts.

Keywords: Urban Logistics, City Logistic, Urban Freight Transport, Last Mile Delivery, Sustainability, E-Grocery, Customer Acceptance, UTAUT2.

Citation: Sonneberg, M.-O., Werth, O., Kohzadi, H., Kraft, M., Neels, B., Breitner, M.H. (2019): Customer Acceptance of Urban Logistics Delivery Concepts. *IWI Discussion Paper Series*, 91, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix P: Individually Optimized Commercial Road Transport: A Decision Support System for Customizable Routing Problems

Authors: Max Leyerer, Marc-Oliver Sonneberg, Maximilian Heumann, Tim Kammann, and Michael H. Breitner

Outlet: Sustainability, *Special Issue on Sustainable Urban Logistics*

Link: https://doi.org/10.3390/su11205544

Abstract: The Vehicle Routing Problem (VRP) in its manifold variants is widely discussed in scientific literature. We investigate related optimization models and solution methods to determine the state of research for vehicle routing attributes and their combinations. Most of these approaches are idealized and focus on single problem-tailored routing applications. Addressing this research gap, we present a customizable VRP for optimized road transportation embedded into a Decision Support System (DSS). It integrates various model attributes and handles a multitude of real-world routing problems. In the context of urban logistics, practitioners of different industries and researchers are assisted in efficient route planning that allows for minimizing driving distances and reducing vehicle emissions. Based on the design science research methodology, we evaluate the DSS with computational benchmarks and real-world simulations. Results indicate that our developed DSS can compete with problem-tailored algorithms. With our solution-oriented DSS as final artifact, we contribute to an enhanced economic and environmental sustainability in urban logistic applications.

Keywords: Vehicle Routing Problem, Decision Support System, Design Science Research, Green Information System, Urban Logistics.

Citation: Leyerer, M., Sonneberg, M.-O., Heumann, M., Kammann, T., Breitner, M.H. (2019): Individually Optimized Commercial Road Transport: A Decision Support System for Customizable Routing Problems. *Sustainability*, 11(20), article 5544.

Appendix Q: Chancen, Herausforderungen und Voraussetzungen von Cargotram-Projekten

Authors: Marc-Oliver Sonneberg, Marvin Hempen, Johannes Vollert, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 93, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/K_93_IWI_DP.pdf

Abstract: Diese Arbeit behandelt das Konzept einer Cargotram für den innerstädtischen Transport von verschiedenster Güterarten. Neben der theoretischen Betrachtung jener in der Literatur, wurden mit Blick auf die Praxis erfolgreiche und misslungene Implementierungen verschiedener europäischer Städte beleuchtet. In der Folge werden Chancen und Herausforderungen abgeleitet. Eine detaillierte Beschreibung bedeutender Erfolgsfaktoren und potenzieller Hindernisse, sowie deren Literaturanalyse dienen weiterhin als Grundlage für eine Anwendungsanalyse der urbanen Logistik von Städten. Anhand der erarbeiteten Kriterien gibt diese Arbeit Handlungsempfehlungen für eine mögliche Implementierung der Cargotram auf Basis des vorhandenen Straßen-bahnnetzes in der Stadt Hannover. Die Ergebnisse zeigen, dass der Erfolg des Konzeptes durch die Städte selbst beeinflusst wird, dabei stellen auch in Hannover die Infrastruktur, Finanzierung, Regulierung und Stakeholder essenzielle Aspekte da.

Keywords. Urbane Logistik, Cargotram, Güterstraßenbahn, Gütertransport.

Citation: Sonneberg, M.-O., Hempen, M., Vollert, J., Breitner, M.H. (2019): Chancen, Herausforderungen und Voraussetzungen von Cargotram-Projekten. *IWI Discussion Paper Series*, 93, Hannover (Germany): Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Appendix R: Decision Support for Sustainable and Resilience-Oriented Urban Parcel Delivery

Authors: Max Leyerer, Marc-Oliver Sonneberg, Maximilian Heumann, and Michael H. Breitner

Outlet: EURO Journal on Decision Processes, *Special Issue on Environmental Decisions*

Link: https://doi.org/10.1007/s40070-019-00105-5

Abstract: The worldwide trend of urbanization, the rising needs of individuals, and the continuous growth of e-commerce lead to increasing urban delivery activities, which are a substantial driver of traffic and pollution in cities. Due to rising public pressure, emission-reducing measures are increasingly likely to be introduced. Such measures can cover diesel bans or even entire car-free zones, causing drastic effects on delivery networks in urban areas. As an option to reduce the risk of a regulation-induced shock, we present a resilience-oriented network and fleet optimization. We propose an innovative parcel delivery concept for last mile delivery (LMD) operations and develop an optimization model to support tactical planning decisions. Our model minimizes overall operating costs by determining optimal locations for micro depots and it allocates transport vehicles to them. An adjustable CO_2-threshold and external costs are included to consider potential regulatory restrictions by city authorities. We implement our model into a decision support system (DSS) that allows analyzing and comparing different scenarios. We provide a computational study by evaluating and discussing our DSS with an example of a mid-sized German city. Our results and findings demonstrate the trade-off between cost and emission minimization by quantifying the impacts of various fleet compositions. The proposed logistics concept represents an option to achieve environmentally friendly, cost-efficient, and resilient LMD of parcels.

Keywords: City Logistics, Environmental Sustainability, Resilience, Last Mile Delivery, Decision Support System.

Citation: Leyerer, M., Sonneberg, M.-O., Heumann, M., Breitner, M.H. (2019): Decision Support for Sustainable and Resilience-Oriented Urban Parcel Delivery. *EURO Journal on Decision Processes,* **7**, pp. 267-300.

Appendix S: Trends of Top Information Systems Research by Region, Outlet, and Emergence

Authors: Nadine Guhr, Marc-Oliver Sonneberg, Jens H. Passlick, Oliver Werth, and Michael H. Breitner

Outlet: Journal of Information Systems and Technology Management

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Introduction

The Association for Information Systems (AIS) states that "the history of any academic field plays an important role in shaping the field's present state and giving the field its unique identity. [...] It is important for all involved to study its past to understand its present, and to guide" (AIS, 2019a) and bridge it to its possible future (Bjørn-Andersen & Clemmensen, 2017). Goyal et al. (2018), who analyzed temporal trends in four top information systems (IS) journals and identified emergent themes that have begun to gain prominence in the IS research domain encourage other researchers to broaden their conversation by including a broader set of journals. Motivated by these statement and the need to avoid focusing solely on journals and research themes, our research paper focuses on shifts in research behavior and the development of the IS research domain, including geographical distinctions, differences in research fields, and trends in research fields and outlets (journals and conferences) to "provide important input in setting directions for future research" (Webster & Watson, 2002, p. xiii).

Scientific articles in the IS domain have gained increasing interest along with the rapid growth of published articles over the last several decades (Buhl et al., 2012; Galliers & Whitley, 2007; Hassan & Mathiassen, 2018; Stein et al., 2016). A representative example of the rising number of articles is the ICIS, where the number of the overall publications increased from 94 articles in the year 2000 to 345 in 2015 (AIS, 2019b). Given the variety of topics and the interdisciplinarity of the IS research domain, multiple research choices exist. The sheer dynamism of IS and information technologies (IT), the variety of topics and the interdisciplinarity of the IS research domain offer a broad range of areas for investigation.

To understand the development of the IS research domain, it is important to understand how the research landscape has changed (Stein et al., 2016) and how scientific disciplines have evolved (Straub, 2006). There is a need for a strong description of the origins and the development of IS research in different regions. To the best of our knowledge, no recent scientometric research on the development of IS research includes such a large database that looks not only at the trends but also at geographical differences and publication behavior in top IS journals and conferences.

To fill this gap in the literature, we review all AIS Senior Scholars' Basket of Eight (AIS Bo8) publications and publications in the proceedings of the ICIS over a 16-year period to answer the following research questions:

RQ1: What is the regional distribution of publications in the AIS Bo8 and the ICIS?

RQ2: How has publication behavior changed by region, and what are the greatest changes?

RQ3: Where – in terms of region and outlet – do IS research trends emerge, and how have these changed over time?

To address these research questions, we conducted a scientometric study. We generated our data by reviewing the journals of the AIS Bo8 and the Proceedings of the ICIS between 2000 and 2015 to create a massive database containing information from 6,692 research papers.

In Section 2, we argue for the importance and relevance of contemporaneous reports of IS research that take into account geographical differences as well as the differences between journals and conferences as a means of developing a detailed understanding and history of the IS research domain. Section 3 describes the multistage research process. This is followed by a presentation of the results of our analysis in Section 4. Following the discussion and implications in Section 5, we conclude by identifying limitations and providing an outlook for further research (Sections 6 & 7).

Related Work and Geographical Diversity

The comparatively young IS research domain emerged from several reference disciplines characterized by diverse research domains with regard to methods, theories, and topics (e.g., Palvia et al., 2015). A representative example of the correlation with other disciplines was the introduction of a discussion held at the first ICIS in 1980. Keen (1980, p. 10) stated, “Since MIS [Management Information Systems] is a fusion of behavioral, technical and managerial issues, there is no obvious or single reference discipline”. With this fragmentation of the research domain, Keen (1980, p. 18) further concluded, “It would be impossible to identify a narrow set of topics that constitute MIS research”. The resulting discussion has been dominated by the discourse of paradigms and diversity (e.g., Lowry et al., 2004; Straub & Anderson, 2010), methods used (e.g., Palvia et al., 2015), topics and trends (e.g., Goyal et al., 2018), and the value and identity of IS research (e.g., Neufeld et al., 2007).

Because research fields are already difficult to identify, detecting the source of such emerging research fields might be even more complex. In this context, literature reviews, meta-analyses, and scientometric analyses are useful tools for analyzing and improving the progress of research in the IS research domain. In the past few years, many researchers have published literature reviews including objective methodologies, such as text mining (e.g., Goyal et al., 2018; Hirschheim & Klein, 2012; Sidorova et al., 2008; Stein et al., 2016), meta-analysis (e.g., Everard et al., 2017; Palvia et al., 2015), and scientometric analysis (e.g., Lowry et al., 2004; Wagner et al., 2017), to provide a periodic introspection that can show and improve the progress of research in the IS research domain. As mentioned by Schryen et al. (2015), reviews of the literature can revitalize knowledge development and can contribute to scientific progress from both the revolutionary and the cumulative perspective (Webster & Watson, 2002). A first review of related work showed that the IS research community is influenced by organizational needs (Vessey et al., 2002), interdisciplinary connections (Choi et al., 2011; Hassan, 2014), outlet preferences (Chen & Hirschheim, 2004; Loebbecke & Leidner, 2012; Te’eni, 2013; Te’eni et al., 2015), and geographical diversity (e.g., Galliers & Whitley, 2007; Lowry et al., 2007; Lowry et al., 2004; Straub & Anderson, 2010; Stein et al., 2016).

Although the IS research domain is increasingly global, geographical diversity might be a source of trends given that “many US authors use no European contributions as references” (Suomi, 1993, p. 347), whereas “Europeans refer mostly to American literature” (Suomi, 1993, p. 347). Suomi’s study was based on a citation analysis of one volume per journal (six American and six European based) from 1990. Galliers and Meadows (2003) similarly demonstrated that there was a strong relationship between the “nationality” of authors and the “nationality” of the journals in which the authors’ articles were published. Citation patterns were also the subject of Lowry et al. (2007). In their article, they highlight the problem of underrepresentation of researchers and institutions outside North America. A more recent editor’s comment by Straub and Anderson (2010) notes that American dominance is slightly decreasing. They indicate “a hopeful trend in moving toward greater parity of regional representation in our leading journals” (Straub & Anderson, 2010, p. iv). Their investigation was based on the geographical author affiliation of published articles in the Management Information Systems Quarterly (MISQ). Specifically, from 2000 to 2004, the share of North and South American articles was approximately 85%, while from 2005 to 2009, this share decreased to 74.4%. Another study by Lowry et al. (2004) showed that researchers agree that MISQ and Information Systems Research (ISR) are the top research journals, regardless of geographic region. However, the data of their study revealed salient differences in perceived journal quality. North American researchers tend to favor management-science- and decision-science-oriented journals (e.g., Management Science and Decision Support Systems) more than European researchers do (Lowry et al., 2004). Furthermore, as mentioned by Lowry et al. (2004), European researchers tend to prefer active participation in research, and they also tend to prefer more interpretivist- and practitioner-oriented journals than North American researchers do. Another research work with a geographical focus is the work of Pouloudi et al. (2012). They developed a profile of IS research for the Mediterranean region (Pouloudi et al., 2012). Avison et al. (2008) considered the paradigmatic, thematic, and geographical development of Information Systems Journal (ISJ) publications from 1991 to 2007 (see also Avison & Fitzgerald, 2012). Whitley and Galliers (2007) examined the European Conference on Information Systems (ECIS) proceedings from 1993 to 2002 and revealed that European research has its own profile and is not directly influenced by North American research. This point was underlined by Stein et al. (2016), who analyzed all papers published in ECIS proceedings during a 10-year period (2003-2012). They focused on the current research profile of the European IS research community, highlighting three main characteristics and the corresponding keywords "(1) continuation of the traditional European IS research profile as developed in the first decade… ; (2) convergence with aspects of the North American tradition …; and (3) the development of a distinct perspective and approach to DS …" (Stein et al., 2016, p.12). Buhl et al. (2012) focused on the context of regional diversity in their research article on German-speaking countries in the Business and Information Systems Engineering journal and proposed recommendations that represent a long-term strategic realignment of the strategic information systems community. Other scientometric studies have also shown that perceptions of journal quality can be affected by geography (Galliers & Meadows, 2003).

With regard the previously described increasing parity between different geographic regions, both journal quality and geography may be influential. Moving toward the organizational needs perspective, Vessey et al. (2002) investigated the core topics of three IS journals, ISR, Journal of Management Information Systems (JMIS), and MISQ, and two journals from other domains with a high share of IS content, Management Science (MS) and Decision Sciences (DS). In terms of the diversity of these North American journals from 1995 to 1999, JMIS had the broadest diffusion/variance in terms of topics, while MISQ had the smallest variety of topics. When analyzing the main topics of these five journals, organizational concepts, problem domain-specific concepts, and systems/software were most frequently discussed. Because organizational concepts were by far the strongest main topics, relevant subtopics identified were IT usage/operation, technology transfer, IT impact, and management of computing function. The fragmented IS foundation "created an interdisciplinary space that straddles the discourses of all these disciplines" (Hassan, 2014, p. 808). This growing variety of different research topics and vocabularies is seen as a weak point in the clear identification of IS subjects (Barki et al., 1993). The interdisciplinary IS foundation mentioned by Keen (1980) was also addressed by Choi et al. (2011). They analyzed keyword networks in IS research journals (MISQ, JMIS, ISR, Information & Management, Decision Support Systems) over the period from 1999 to 2008 and revealed that the keyword diffusion process is a hierarchical one in which clusters are built under popular keywords. Because those clusters are strongly related, they suggest that interdisciplinary terms might have the potential to lead future research trends. Furthermore, Palvia et al. (2015) conducted a meta-analysis in their research work and focused on topic and methodological trends. They indicated that there was a partial mismatch between research and business needs.

Regarding outlet preferences, top IS journals can be differentiated from conference proceedings and lower-ranked journal publications. The results of a comprehensive study by Lowry et al. (2004) showed that researchers in the IS research domain rated MISQ and ISR as the top journals. Te'eni et al. (2015) stated that "conference papers can only be used as a starting point" (Te'eni et al., 2015, p. 566) for the discussion of topics. This statement leads to the suggestion that instead of top IS journals, conference proceedings are the source of new IS research. Furthermore, Loebbecke and Leidner (2012) suggested that researchers "may appreciate the chance to publish an innovative idea more quickly, avoiding long review rounds and the rigor required for publishing in premier journals" (Loebbecke & Leidner, 2012, p. 431) compared to lower-ranked journals. Top IS journals are not the trendsetters in IS research. Following Te'eni (2013), the gap between top IS research and conferences should be improved with regard to their interaction and exchange. In contrast to other research disciplines, such as computing science, the reputation of conference proceedings should improve through high-quality review procedures that are comparable to those of top IS journals (Chen & Konstan, 2010). The ICIS was an exception by conducting high-quality double-blinded reviews, resulting in worldwide acceptance by top IS researchers (Chen & Hirschheim, 2004).

Research Methodology

In our research article we followed the argument by Sidorova et al. (2008) that the identity construction and the core of a research discipline can be revealed by "aggregating individual research papers at a higher semantic level" (Sidorova et al., 2008, p. 470). In this context our research is based on a scientometric analysis (including, i.a., a keyword search and an extended LSI search using an LSI tool (Koukal et al., 2014)). As described by Lowry et al. (2004), scientometrics can be defined as "the scientific study of the process of science" (Lowry et al., 2004, p. 30), including different methodological approaches such as, e.g., systematic literature reviews, meta-analyses, and citation analyses. Scientometrics focuses more on policy studies than on the pure statistical analysis of publications, as in the case of bibliometrics (Hassan & Loebbecke, 2010) and are recommended to advance the ongoing improvement and evaluation of an academic discipline (Lewis et al., 2007). Scientometrics has also been referred to as "knowledge domain visualization" or "domain mapping" (Hook & Börner, 2005). In research, there are different reasons why researchers conduct descriptive scientometric studies of a particular research domain, such as to understand the identity of a scientific discipline or research domain (Serenko et al., 2009). Overall, scientometric analysis is seen as a useful tool for analyzing and improving the progress of research in the IS research domain by exploring the entire intellectual core of a research domain instead of concentrating on its individual works (Serenko et al., 2009; Sidorova et al., 2008). In the past few years, many researchers have published scientometric analysis on topics in IS research (e.g., the epistemological structure of the IS domain in general) to provide a periodic introspection that can show and improve the progress of research in the IS research domain (e.g., Hassan & Mathiassen, 2018; Hirschheim & Klein, 2012; Lowry et al., 2004; Lowry et al., 2013; Sidorova et al., 2008). In research, two general scientometric approaches are distinguished: the normative approach and the descriptive approach (Neufeld et al., 2007). As mentioned by Serenko et al. (2009) "the purpose of the normative perspective is to establish norms, rules, and heuristics to ensure a desirable discipline progress. In contrast, the objective of the descriptive approach is to observe and report on the actual activities of the field's scholars" (Serenko et al., 2009, p. 5). In this project, the descriptive method is followed because it fits better with the underlying research questions and the overall goal of this research work which is to provide a holistic and comprehensive picture of current research on the evolution of trends, major research fields, regional distribution of publications, and changes in publication behavior in IS research. This approach underscores the type of information that is needed, informs the selection of relevant literature, and guides the following analyses. To structure our research process adequately and to make it comprehensive and clear, our approach is oriented toward the approach of Bandara et al. (2015). Because the analysis of thousands of documents is time consuming, we divided our research approach into four different phases, which enabled a structured and efficient approach (compare Figure 1).

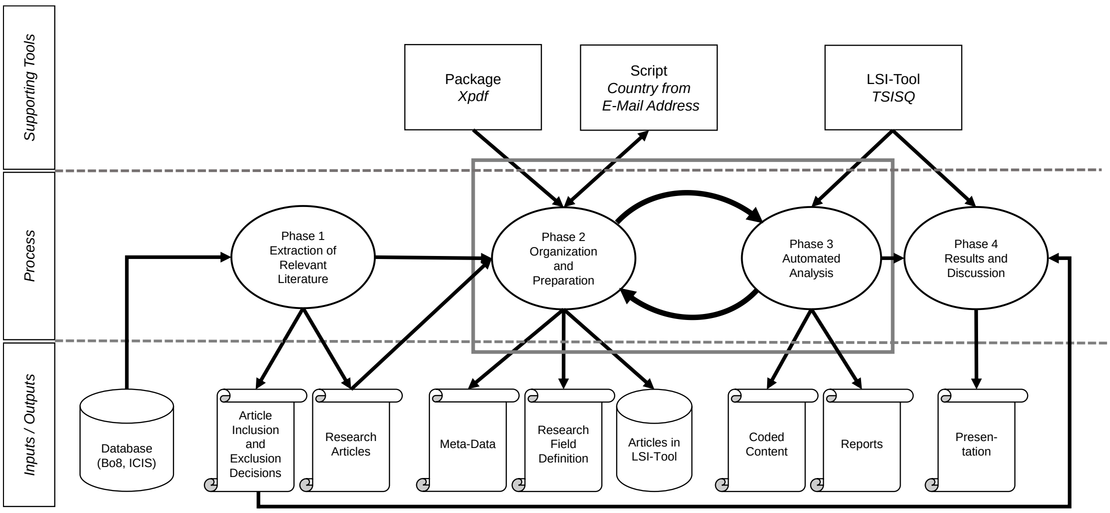

Figure 1. Research methodology and process model

Phase 1 is characterized by problem identification and formulation and subsequently by the extraction of relevant literature. As in any scientometric study, our study emphasizes that the selection of journals and/or conference proceedings plays a central role. Although selecting a single journal or a conference proceeding may, in some cases, provide a clear research scope, in our case, this was not expedient because we wanted to investigate how the IS domain has changed over time, how trends develop, which geographical differences exist, and how publication behavior has changed. We also wanted to discuss the differences between conference papers and journal articles, which justified the inclusion of the ICIS proceedings. Börner (2010) mentioned that the phase of data acquisition is one of the most time-consuming phases in scientometric research because approximately 80 percent of a typical project's total effort is spent on data acquisition and preprocessing. The population size for our research focus (complete academic IS literature) is too large to conduct a total population study. Therefore, we used as a sample group all publications of the AIS Bo8 journals and the ICIS proceedings in the time period from 2000 to 2015. Our study integrates all journals of the AIS Bo8 and all articles of the ICIS proceedings in the previously mentioned time period because most IS scholars agree that these outlets are the most significant (Hassan & Mathiassen, 2018). We downloaded all publications from several sources and imported them into a literature management tool. We removed different elements, such as book reviews, errata notes, and editorials, which we documented in an exclusion list. Table 1 presents the number of articles per outlet.

Table 1. Number of articles differentiated by particular outlet

Outlet (journal/conference)	**Abbr.**	**# Articles**	**Rel. Share**
European Journal of Information Systems	EJIS	562	54,30%
Information Systems Journal	ISJ	309	
Information Systems Research	ISR	551	
Journal of the Association for Information Systems	JAIS	381	
Journal of Information Technology	JIT	345	
Journal of Management Information Systems	JMIS	619	
Journal of Strategic Information Systems	JSIS	287	
Management Information Systems Quarterly	MISQ	574	
International Conference on Information Systems	ICIS	3,058	45,70%
	∑	**6,692**	**100%**

Phase 2 aimed to organize and prepare the literature. We structured and organized the articles and assigned corresponding metadata. For the determination of geographical trends, we developed an algorithm to add this information by using the country suffix of e-mail addresses to assign the corresponding author to a country. Many publishers, such as Elsevier, accept this restriction to only the first author (Straub & Anderson, 2010). With the aid of the package Xpdf, we converted the .pdf files to .txt files, which facilitated the further processing of the documents. Before the investigation of trends within the interdisciplinary research domain of IS can be conducted, we had to cluster topics in appropriate research fields. Specific IS research topics are covered under these research fields. Each research field contains one or more research topics equipped with a text module that is necessary for the assignment of articles. To do so, we analyzed topics of various track descriptions of the ICIS and special issues of AIS Bo8 journals. Based on this, we created a table containing different topics and corresponding descriptions. To group the topics into reasonable research fields, we used an inductive procedure. Within this iterative process, research fields were created, renamed, replaced, or consolidated along with a running adjustment of the corresponding text module. As a result, we identified 22 research fields consisting of a multiplicity of topics to cover all topics within 16 years of IS research in the mentioned outlets (see Table 2).

Table 2. Compilation of research fields	
Business Process Management	IS Projects & IS Development
Contribution of Applied Science	IS Security & Privacy
Data Science & Business Analytics	IS Strategy & (Out-)Sourcing
E-Business & E-Government	IT Implementation, Adoption, & Use
Funding of Innovations	Knowledge Management
Human Behavior & Cultural Aspects	Mobile Information Systems
Impacts of IT/IS	Open Source Software & Open Innovations
IS Curriculum & Education	Research Methods & Philosophy
IS History	Service Science in IS
IS in Healthcare	Social Media & Digital Collaboration
IS in Organizations & Society	Sustainability

In Phase 3, the literature database was analyzed. We made use of an LSI tool called TSISQ, which assigns articles to research field definitions (Koukal et al., 2014). LSI is an automated literature analysis approach using mathematical techniques to ascertain patterns between articles. In contrast to a typical keyword search, different synonyms and paraphrases are non-problematic, and enormous savings of time are possible when identifying the relevance of resulting articles (Koukal et al., 2014). For our investigation, we inserted our database consisting of 6,692 articles into TSISQ, which is located on a non-public server due to access restrictions of the publications. For each article, the tool conducted an LSI process, and the resulting queries were stored in a separate database that served as basis for our further investigations. After we inserted our developed definitions for the different IS research fields, these passed through this LSI process as well. The database and our research field definitions were compared and related articles were presented and sorted by content-specific relevance. Throughout the entire LSI process, we manually checked the results of TSISQ to ensure the correct assignment of articles to research fields.

In Phase 4, we present our results in terms of the regional distribution of publications in the AIS Bo8 and the ICIS, the change in publication behavior, and the emergence and change of IS research fields and trends over time. In order to carry out a meaningful analysis of the temporal change in publication behavior, and the emergence and change of IS research fields and trends over time, we divided the entire period of 16 years into four year segments describing a time span of four years (YS). This is justified by the fact that we needed a sufficient number of publications per YS and outlet to carry out a meaningful analysis. This period allows enough time for the analysis of temporal changes in publication behavior and enough time for research fields to go through a large part of its life cycle (Sidorova et al., 2008). In order to reflect the time span in each segment equally, we limited our analysis to the time period from 2000 to 2015 because JAIS began publishing in 2000.

Results

Regional Distribution of Publications in the AIS Bo8 and ICIS

In this section, the results of our investigation are presented by answering the first research question with regard to the regional distribution of publications and their corresponding outlets. As explained, the foundation for our investigation is formed by a database of 6,692 articles consisting of 3,061 publications in the ICIS proceedings and 3,631 AIS Bo8 journal publications. Table 3 presents a time-independent classification of articles by continent and chosen country (groups) divided into the number of published articles in total.

Table 3. Assignment of articles to geographical regions differentiated by outlet

Continent *Country (group)*	**# Total articles**	**# ICIS articles**	**# AIS Bo8 articles**	**Continent** *Country (group)*	**# Total articles**	**# ICIS articles**	**# AIS Bo8 articles**
North America	3,654	1,529	2,125	Asia	852	476	376
Europe	1,738	818	920	*China*	*319*	*174*	*145*
Germany, Austria, and Switzerland	*595*	*454*	*141*	*Singapore*	*276*	*200*	*76*
Great Britain	*574*	*140*	*434*	*Korea*	*92*	*39*	*53*
Scandinavia	*278*	*108*	*170*	*Taiwan*	*63*	*19*	*44*
Northern Mediterranean	*155*	*64*	*91*	*Further Asian countries*	*102*	*44*	*58*
Benelux Union	*124*	*45*	*79*	South America	18	10	8
Further European countries	*12*	*7*	*5*	Africa	14	10	4
Australia	359	188	171	No country identifiable	57	30	27

Focusing on the overall continental distribution, in total North American researchers published approximately 55% (3,654) of the worldwide articles in these IS outlets, followed by Europe with 1,738 (approx. 26%), and Asian countries with 852 articles (approx. 13%). Less than 7% (448 articles) were from other regions of the world (Australia, South America, and Africa). These included 57 articles in which the country of the corresponding author was not identifiable. We merged Australia with Oceania because of the comparatively low share of Oceanian articles. Due to the small number of published articles, South American and African regions were not subdivided into countries. Regarding Europe, most of the articles were published by researchers from Germany, Austria, and Switzerland (595 articles) as well as Great Britain (UK and Ireland) (574 articles). Scandinavian researchers (from Norway, Sweden, Finland, Denmark, and Island) produced 278 articles (4%), Northern Mediterranean researchers (consisting of Portugal, Spain, France, and Italy) produced 155 articles (2.3%), and researchers from the Benelux Union (Netherlands, Belgium, and Luxembourg) produced 124 articles (1.8%). The remaining publications were grouped as further European countries (approx. 0.1%). Analyzing Asia, researches from China and Singapore published 319 and 276 articles, respectively, approximately 9% of the total number of publications. Researchers from Korea published 92 articles (slightly more than 1%), and researchers from Taiwan produced 63 articles (less than 1%); these are mentioned separately, while research articles from other Asian countries are grouped together.

Next, geographical appearance in the ICIS proceedings and the AIS Bo8 journal publications was investigated in more detail. North American publications dominated the AIS Bo8 journals with a total of 2,125 articles from 2000 to 2015, representing nearly 60% of all articles. In Europe and North America, there were more articles published in the AIS Bo8 journals than in the ICIS proceedings. Regarding the other continents, there were (slightly) fewer articles published in AIS Bo8 journals. Intracontinental differences were clearly visible in Europe and Asia. While researchers from Germany, Austria, and Switzerland were commonly present in the ICIS proceedings (454 articles), the majority of publications from the UK and Ireland were published in the AIS Bo8 journals (434 articles). In Asia, measured at share, China and Singapore were quite evident in the ICIS proceedings, but Singapore was less represented in the AIS Bo8 journals. On the contrary, articles by Korean and Taiwanese researchers as well as those from other Asian countries were published in the AIS Bo8 journals and comparatively less in the ICIS proceedings.

Temporal Change in Publication Behavior – A Geographical Perspective

Based on the above findings, the following investigations are focused on the detection of the temporal change in publication behavior. Figure 2 visualizes this change by application of YS with regard to ICIS proceedings and AIS Bo8 journal publication numbers (YS1 2000-2003, YS2 2004-2007, YS3 2008-2011, and YS4 2012-2015). For visualization and comparability reasons, Figure 2 is narrowed to continental trends, while the investigation of Table 4 includes the specific country-related distribution. The number of articles in the AIS Bo8 journals is continuously rising, and ICIS proceeding articles show a rapid increase, especially from YS2 to YS3. Upon investigation, the number of articles from Europe, Australia, Asia, and the other continents (South America, Africa, and unidentifiable) nearly doubled each YS. Except for YS2 to YS3, the North American researchers are quite similarly represented by comparing the number of articles between two segments. Regarding YS4, European and North American publications are at nearly the same level, which became apparent regarding the past trend. Analyzing the AIS Bo8 journal publications from YS1 to YS3, a steady rise in all regions is observable. The development in YS4 follows the primary development except in North America. The number of North American publications is slightly decreasing, although the number of overall articles is rising. To recap, in both outlets, the number of publications is increasing, while all regions over the time period show an increase, with the exception of North America in the last YS.

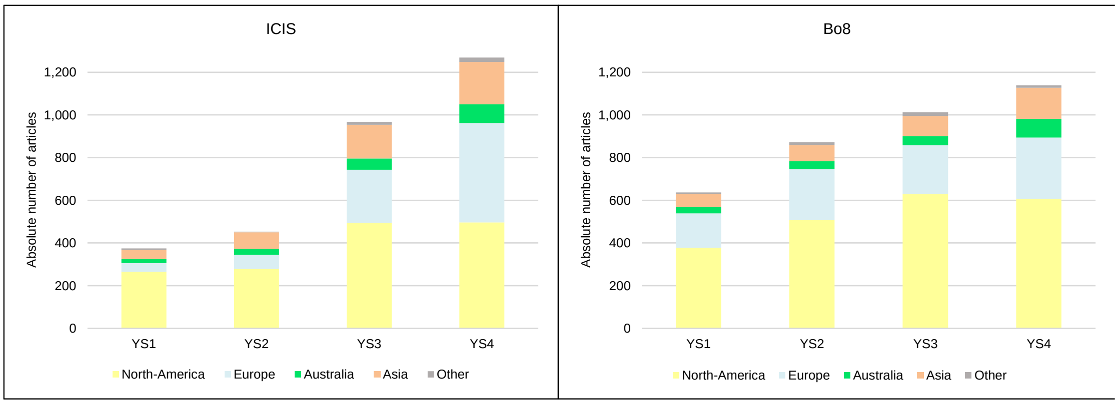

Figure 2. Absolute number of articles per YS and region in comparison to outlets

For deeper investigation and to understand how these continental trends are composed, the relative shares for continents and countries or respective country groups are presented in Table 4. The share of North American articles decreased from YS1 to YS4 especially for the number of publications in ICIS proceedings. Regarding Europe, for ICIS proceedings, the publication number continually grew from approximately 11% to approximately 37%, while for the AIS Bo8 journals, the relative share fluctuated by approximately 25%. For Australia, this shifting trend is also obvious, with little variation of approximately 1%. Considering the Asian countries, we see an increasing trend from YS1 to YS3 with a decrease in YS4 with regard to ICIS proceeding articles and a relative steady rise from 10% to 13% in the AIS Bo8 journals. For South American, African, and other countries, no pattern is identifiable because of small publication numbers.

Table 4. Relative share of articles in terms of regional distribution and outlet in comparison to the YS

Continent *Country (group)*	**ICIS**				**AIS Bo8**			
	YS1 (2000-2003)	**YS2 (2004-2007)**	**YS3 (2008-2011)**	**YS4 (2012-2015)**	**YS1 (2000-2003)**	**YS2 (2004-2007)**	**YS3 (2008-2011)**	**YS4 (2012-2015)**
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
North America	70.85%	61.15%	51.09%	39.09%	58.88%	57.48%	61.28%	54.16%
Europe	10.70%	15.01%	25.75%	36.72%	25.08%	27.10%	22.18%	25.60%
Germany, Austria, and Switzerland	*1.07%*	*3.31%*	*11.27%*	*25.85%*	*0.78%*	*1.93%*	*3.70%*	*7.05%*
Great Britain	*4.29%*	*7.06%*	*5.69%*	*2.92%*	*16.36%*	*16.33%*	*8.27%*	*8.92%*
Scandinavia	*2.41%*	*1.32%*	*4.03%*	*4.33%*	*3.58%*	*4.54%*	*5.54%*	*4.37%*
Northern Mediterranean	*0.53%*	*1.55%*	*3.00%*	*2.13%*	*1.87%*	*1.81%*	*2.72%*	*3.03%*
Benelux Union	*1.87%*	*1.77%*	*1.76%*	*1.10%*	*2.49%*	*2.38%*	*1.95%*	*1.87%*
Further European countries	*0.53%*	*0%*	*0%*	*0.39%*	*0%*	*0.11%*	*0%*	*0.36%*
Australia	5.35%	5.96%	5.48%	6.93%	4.67%	4.31%	4.19%	5.62%
Asia	11.23%	17.22%	16.33%	15.60%	9.65%	8.50%	9.14%	12.93%
China	*2.68%*	*3.97%*	*7.14%*	*6.07%*	*2.80%*	*1.81%*	*3.79%*	*6.42%*
Singapore	*6.69%*	*10.15%*	*6.10%*	*5.52%*	*2.34%*	*2.61%*	*1.65%*	*1.87%*
Korea	*0.80%*	*1.55%*	*0.92%*	*1.58%*	*1.40%*	*1.47%*	*1.46%*	*1.43%*
Taiwan	*0.53%*	*0%*	*1.03%*	*0.55%*	*0.47%*	*1.25%*	*0.98%*	*1.78%*
Further Asian countries	*0.53%*	*1.55%*	*1.14%*	*1.88%*	*2.65%*	*1.36%*	*1.26%*	*1.43%*
South America	0%	0.22%	0.52%	0.32%	0.16%	0.35%	0.19%	0.18%
Africa	0%	0.44%	0.21%	0.47%	0.78%	1.13%	1.56%	0.89%
No country available	1.87%	0%	0.62%	0.87%	0.78%	1.13%	1.46%	0.62%

Focusing on intra-European researchers, the impact of Germany, Austria, and Switzerland within YS1 in both outlets was almost not existent. In the following years, the relative share of publications considerably increased. For ICIS proceeding publications, the share more than tripled from YS1 to YS3, whereas from YS3 to YS4, the share doubled. Regarding AIS Bo8 journal publications, the relative share at least doubled. A similar observation can be made for the Scandinavians, where the relative share of publications in ICIS conference proceedings has doubled. If we investigate Great Britain's researcher development in the ICIS proceedings, the relative share of articles decreased from approximately 7% to only 3%. In the AIS Bo8 journals the relative share in YS3 and YS4 was reduced by approximately half (8%). The other European countries do not follow notable trends, fluctuating approximately 1% or 2% between the YSs. In summary, the number of publications of German, Austrian, and Swiss researchers in both outlets increased over the years, which is the key factor in increasing the relative share of European articles. When investigating differences within Asia, the developments are not as distinct and no generalizations about time-dependent trends are obvious; of course, some small variations exist.

After the regional distributions of publications are presented for ICIS and the AIS Bo8, differences within the various AIS Bo8 journals can be examined. Figure 3 presents the number of articles for all AIS Bo8 journals and their continental distribution over time.

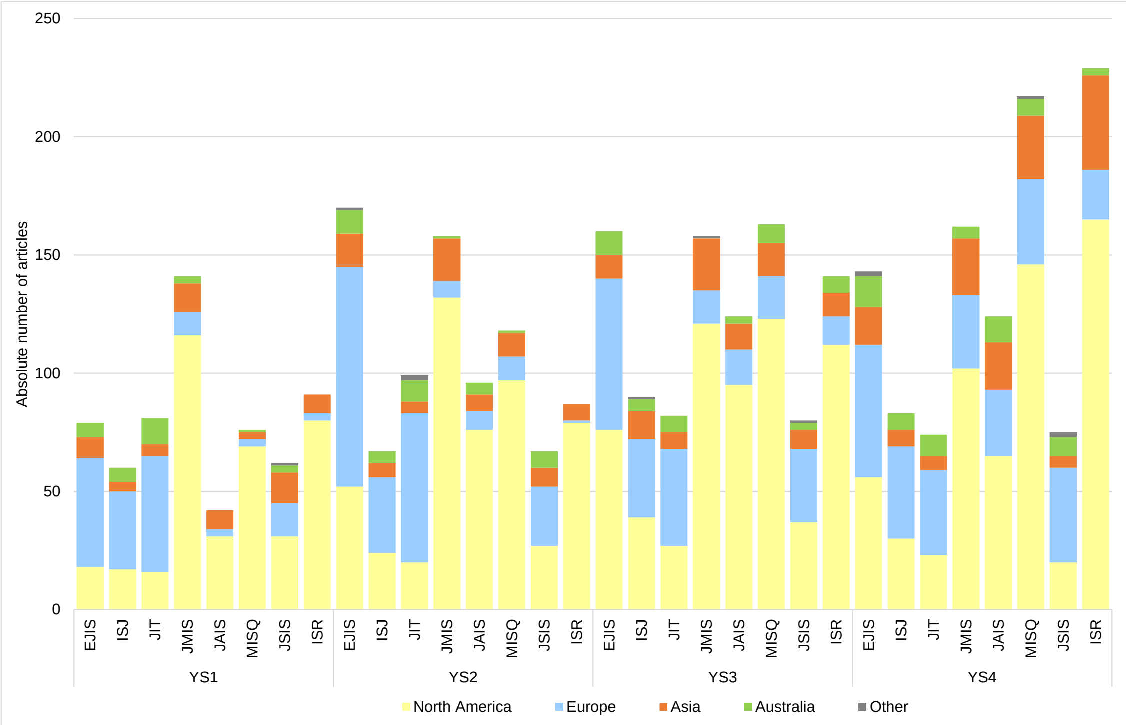

Figure 3. Continental distribution of articles within the Bo8 journals (EJIS, ISJ, JIT, JMIS, JAIS, MISQ, JSIS, and ISR)

As the name suggests, EJIS is one of the leading European IS journals (Dwivedi & Kuljis, 2008). This is confirmed by the results. Almost half of the publications (259 out of 552) were of European origin, and 36% of the articles are published by North American researchers. When comparing these numbers with the sum total of AIS Bo8 from Table 4, it is clear that compared to the average over the years, many European articles and few North American articles were actually published in the EJIS. Asia and Australia are each represented with 9% and 7% respectively. With regard to the temporal distribution, it is remarkable that the number of total publications in the EJIS has declined since YS2. In particular, the number of European publications decreased from YS2 to YS3, whereas the number of North American publications increased over the same period. The number of Asian and Australian articles at least doubled from YS1 to YS4. In addition to the EJIS, there was a surplus of European articles in the ISJ and JIT. Similar to MISQ, JMIS, JAIS, and ISR show a clear spatial origin focus on North America. In all these journals, however, a recognizable internationalization of the origin of the authors can be observed within the last two YSs. A special feature of the ISR is the comparatively high number of Asian articles in recent years. The JSIS cannot be assigned to either trend. Initially more North American, it is now more influenced by European researchers and their publications.

Both outlets (ICIS and AIS Bo8 journals) show an increasing number of articles, although the increase within ICIS proceedings is much more obvious with a tripling from YS1 to YS4. Regarding the continental distribution, North America was the leading geographic region in both outlets over the investigated period, whereas the European countries were mainly represented in the ICIS proceedings. Asian countries were quite important with comparatively high publications in China and Singapore. Australia followed the slightly increasing trend, while South American, African, and other publications remained rare in top IS research in the ICIS proceedings and the AIS Bo8 journals. When analyzing the individual AIS Bo8 journals, there are journals with a strong focus on North American research and journals with a slight European focus and vice versa (compare Figure 3). A journal dominated by Asian or Australian researchers does not exist.

Development of IS Research Fields in Terms of Region and Outlet

To further investigate trends in terms of region and outlet over time, it is necessary to conduct calculations to obtain absolute and relative shares. Table 5 serves as the foundation for the following charts and figures to identify patterns in IS research fields. Table 5 presents the number of publications per research field grouped by YS as well as by outlet and presents the absolute number of matches and the relative share. The relative shares are determined by dividing the number of absolute articles of a research field within an outlet and a YS by the amount of overall publications within this research field within an outlet and a YS. These relative shares serve as input for the following investigations.

Table 5. Absolute and relative scientific interest by outlet, research field, and time

		YS1 (2000-2003)		**YS2 (2004-2007)**		**YS3 (2008-2011)**		**YS4 (2012-2015)**	
Overall Database of 6,692 articles	AIS Bo8	637		872		1,013		1,114	
	ICIS	374		453		967		1,269	
Research Fields (matches)	**Outlet**	**Abs.**	**Rel.**	**Abs.**	**Rel.**	**Abs.**	**Rel.**	**Abs.**	**Rel.**
E-Business & E-Government (842)	AIS Bo8	83	13.03%	161	18.46%	139	13.72%	144	12.93%
	ICIS	39	10.43%	54	11.92%	101	10.44%	121	9.54%
Service Science in IS (785)	AIS Bo8	65	10.20%	112	12.84%	119	11.75%	140	12.57%
	ICIS	28	7.49%	65	14.35%	94	9.72%	175	13.79%
IS in Organizations & Society (785)	AIS Bo8	54	8.48%	114	13.07%	114	11.25%	425	38.15%
	ICIS	26	6.95%	66	14.57%	103	10.65%	357	28.13%
Contribution of Applied Science (758)	AIS Bo8	96	15.07%	125	14.33%	123	12.14%	116	10.41%
	ICIS	39	10.43%	80	17.66%	94	9.72%	85	6.70%
Social Media & Digital Collaboration (713)	AIS Bo8	43	6.75%	60	6.88%	95	9.38%	118	10.59%
	ICIS	23	6.15%	42	9.27%	133	13.75%	199	15.68%
Human Behavior & Cultural Aspects (664)	AIS Bo8	90	14.13%	110	12.61%	114	11.25%	112	10.05%
	ICIS	30	8.02%	53	11.70%	77	7.96%	78	6.15%
Impacts of IT/IS (651)	AIS Bo8	84	13.19%	115	13.19%	102	10.07%	112	10.05%
	ICIS	32	8.56%	49	10.82%	77	7.96%	80	6.30%
Research Methods & Philosophy (433)	AIS Bo8	39	6.12%	42	4.82%	61	6.02%	80	7.18%
	ICIS	11	2.94%	20	4.42%	59	6.10%	121	9.54%
IS Security & Privacy (319)	AIS Bo8	18	2.83%	28	3.21%	82	8.09%	57	5.12%
	ICIS	11	2.94%	22	4.86%	50	5.17%	51	4.02%
Mobile Information Systems (290)	AIS Bo8	11	1.73%	35	4.01%	31	3.06%	60	5.39%
	ICIS	11	2.94%	13	2.87%	28	2.90%	101	7.96%
IS in Healthcare (259)	AIS Bo8	5	0.78%	32	3.67%	41	4.05%	50	4.49%
	ICIS	1	0.27%	7	1.55%	53	5.48%	70	5.52%
Funding of Innovations (285)	AIS Bo8	17	2.67%	32	3.67%	28	2.76%	35	3.14%
	ICIS	12	3.21%	6	1.32%	39	4.03%	89	7.01%
Knowledge Management (242)	AIS Bo8	17	2.67%	36	4.13%	37	3.65%	36	3.23%
	ICIS	19	5.08%	27	5.96%	33	3.41%	37	2.92%
IS Curriculum & Education (205)	AIS Bo8	14	2.20%	21	2.41%	25	2.47%	17	1.53%
	ICIS	9	2.41%	24	5.30%	43	4.45%	52	4.10%
Data Science & Business Analytics (160)	AIS Bo8	10	1.57%	21	2.41%	22	2.17%	23	2.06%
	ICIS	8	2.14%	14	3.09%	19	1.96%	43	3.39%
IT Implementation, Adoption, & Use (146)	AIS Bo8	9	1.41%	14	1.61%	29	2.86%	18	1.62%
	ICIS	3	0.80%	10	2.21%	27	2.79%	36	2.84%
Business Process Management (123)	AIS Bo8	21	3.30%	10	1.15%	15	1.48%	14	1.26%
	ICIS	2	0.53%	8	1.77%	18	1.86%	35	2.76%
IS Projects & IS Development (93)	AIS Bo8	13	2.04%	16	1.83%	17	1.68%	12	1.08%
	ICIS	5	1.34%	5	1.10%	11	1.14%	14	1.10%
Open Source Software & Open Innovations (90)	AIS Bo8	5	0.78%	1	0.11%	16	1.58%	8	0.72%
	ICIS	7	1.87%	6	1.32%	14	1.45%	33	2.60%
Sustainability (90)	AIS Bo8	5	0.78%	7	0.80%	19	1.88%	11	0.99%
	ICIS	5	1.34%	2	0.44%	17	1.76%	24	1.89%
IS History (87)	AIS Bo8	7	1.10%	17	1.95%	12	1.18%	21	1.89%
	ICIS	4	1.07%	11	2.43%	6	0.62%	9	0.71%
IS Strategy & (Out-)Sourcing (84)	AIS Bo8	1	0.16%	4	0.46%	24	2.37%	15	1.35%
	ICIS	0	0.00%	11	2.43%	9	0.93%	20	1.58%

It must be mentioned that it is quite possible that a publication can be classified into two or even more research fields. For example, a publication that develops a mobile application for mobility is mentioned in the fields of “Service Science”, “Mobile Information Systems”, and “Sustainability”. On the other hand, there are articles that are not assigned to one of the 22 categories. On average, a publication was assigned to 1.21 research fields. From our analysis four different trends in research field development were revealed. These differ in terms of development over time in relation to the number of publications on specific research fields in the AIS Bo8 journals and the publications in the ICIS proceedings. These four different trends are illustrated by four research fields (“Social Media & Digital Collaboration”, “Impact of IT/IS”, “Service Science in IS”, and “Funding of Innovations”) as examples and can be categorized as follows: (1) similarly increasing, (2) similarly decreasing, (3) similarly consistent, and (4) divergent (see Figure 4).

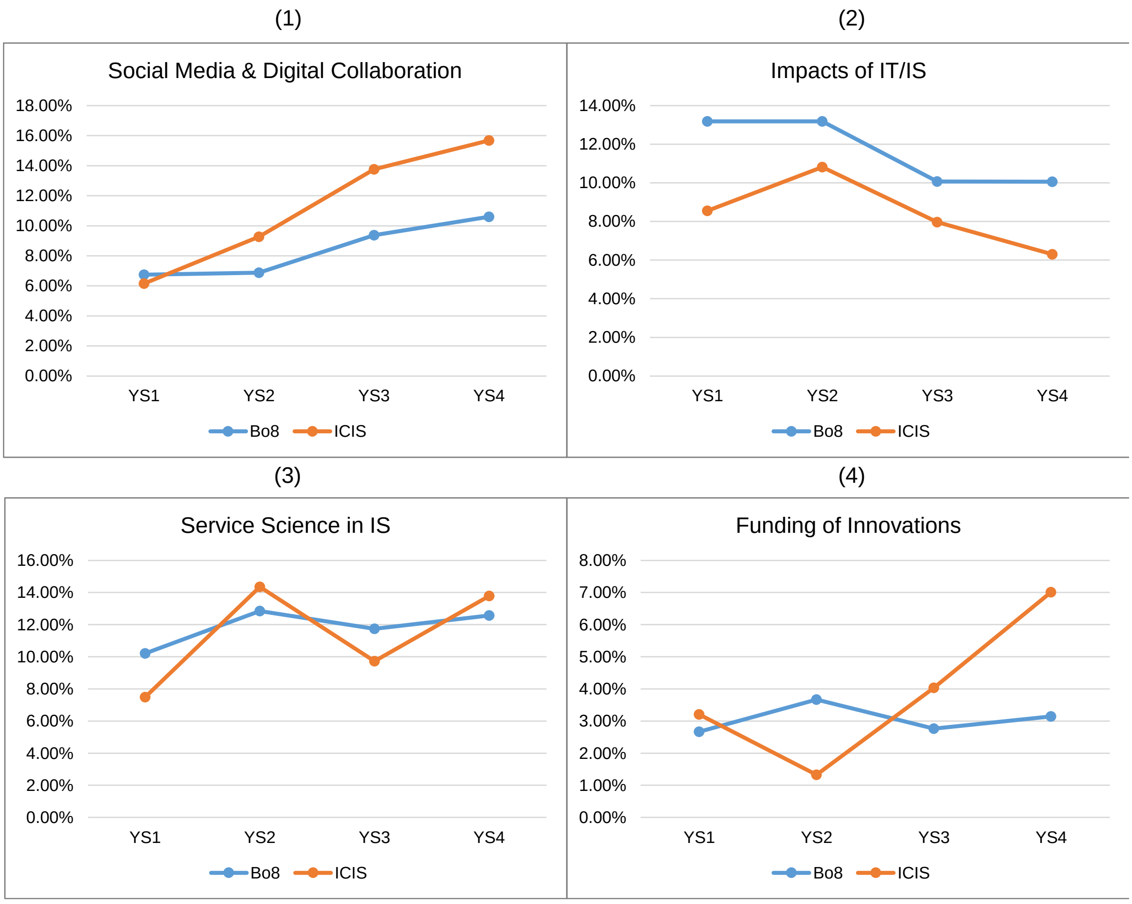

Figure 4. Identified pattern regarding outlet and YS’ for exemplified research

As an example of a research field with a constant increase in the number of publications over time, the research field “Social Media & Digital Collaboration” can be mentioned. There is a similar increase in publications in this research field in both the AIS Bo8 and the ICIS proceedings. It should be noted, however, that the number of publications in the ICIS proceedings increased faster than in the AIS Bo8 journals and more publications were published in the ICIS proceedings over time than in the AIS Bo8 journals. This overall development indicates that these research fields are trending research fields and that the IS community has placed an even greater focus on such research fields. The overall interest in this research field is also reflected in the total number of publications (compare Table 5) as well as in a distinct increasing trend that has interest peaks in both the AIS Bo8 and ICIS. The development of the IS research community and its research interests appear to be somewhat fluid and follow certain trends in society. For example, the number of studies on “Social Media & Digital Collaboration” has grown considerably in number (YS1, YS2) together with the rise of, for example, Twitter and Facebook in 2006 and 2004.

It is obvious that researchers have noticed this trend and its relevance for research. Most AIS Bo8 publications in this field have been published in EJIS, JIT, JAIS, and MISQ (compare Table 6).

Table 6. Share of a journals in a research field

Research Field	**EJIS**	**ISJ**	**ISR**	**JIT**	**JMIS**	**JAIS**	**MISQ**	**JSIS**	**Total**
Contribution of Applied Science	21%	9%	6%	9%	4%	27%	18%	6%	**460**
E-Business & E-Government	26%	9%	8%	17%	11%	7%	10%	12%	**527**
Funding of Innovations	16%	4%	9%	11%	11%	12%	19%	19%	**112**
Human Behavior & Cultural Aspects in IS	22%	13%	3%	20%	4%	15%	16%	8%	**426**
Impacts of IT/IS	17%	10%	3%	19%	19%	9%	14%	9%	**413**
IS in Healthcare	23%	2%	20%	9%	12%	13%	13%	7%	**128**
IS in Organizations & Society	20%	9%	4%	16%	5%	20%	16%	10%	**425**
IS Research Methods & Philosophy	29%	11%	5%	13%	3%	18%	15%	8%	**222**
IS Security & Privacy	17%	7%	8%	8%	12%	18%	19%	10%	**185**
Knowledge Management	17%	9%	6%	19%	8%	10%	20%	13%	**126**
Mobile Information Systems	8%	7%	11%	26%	4%	18%	18%	9%	**137**
Service Science in IS	20%	8%	5%	20%	3%	19%	17%	9%	**436**
Social Media & Digital Collaboration	18%	8%	6%	16%	6%	18%	22%	5%	**316**
Average	19%	8%	7%	16%	8%	16%	17%	10%	

Note: Only research fields with more than 110 publications in total were considered.

This result is in line with the findings of Stein et al. (2016), who came to a similar conclusion in their study of developing research fields with a special focus on the European IS research community. Furthermore, we have identified areas of research (e.g., “IS in Healthcare”) that are in a nascent stage with a steadily increasing tendency and that are considered equally interesting by major IS journals, especially EJIS and ISR, and the ICIS. Although there are a few minor differences in the evolution of other research fields that have been attributed to this category (e.g., “IS in Healthcare”, “Mobile Information Systems”), a similar pattern can be observed regarding the overall increased interest of the IS community in these research fields. The trends observed here suggest some interesting dynamics between society and publishing in leading IS journals and conference proceedings.

Regarding the decreasing overall interests, such trends are evident within research fields with high interest and, therefore, a comparatively high number of articles published over the years. Looking at the research field “Impact of IT/IS” (651 articles), it can be seen that the peak of scientific interest in the AIS Bo8 journals was achieved in YS1 and at the ICIS in YS2, followed by a slight decrease. This pattern can also be observed in other research fields, such as the “Contribution of Applied Science”. These findings illustrate the interesting dynamics in IS research and underline the sometimes short lifespan of research fields, as mentioned by Goyal et al. (2018). In their analysis, these authors made a similar observation regarding the topic of virtual worlds, noting that even one of the hottest topics in research may lose importance in IS research and may wane in the top IS research outlets (Goyal et al., 2018). Most AIS Bo8 publications in this field have been published in EJIS, JIT, and JMIS.

The third trend that we have identified is “similarly consistent”. Although there are differences in the extent of development, the trends are very similar in both the AIS Bo8 and ICIS. Looking at the selected example, “Service Science in IS”, it becomes clear that the number of publications initially increases, then decreases and then rises again and reaches its peak in YS4. Similar developments, which also show fluctuations in the number of publications, can be observed for other fields of research, such as “E-Business & E-Government”, “IS Curriculum & Education”, “Management IT Projects & Development”, and “IS History”.

The deviating evolution of research fields is represented by the category “divergent”. In this category, very different courses of publication trends on specific topics can be observed. As an example, we have chosen the research field “Funding of Innovations”. Contrary development trends can be observed here, which also differ according to the strength and characteristics. Research interest at the ICIS has significantly increased more in recent years than in the AIS Bo8 Journals.

In the AIS Bo8, most publications in this research field were published in the EJIS, MISQ, and JSIS (compare Table 6). Other research fields that have a different development course with regard to the development in the AIS Bo8 and that of the ICIS are “IT Strategy & Outsourcing”, “Business Process Management”, and “Open Source & Open Innovation”. This different development over time can be attributed to different reasons, such as the different times from submission until the paper is published or the perception of the importance and accuracy of individual research fields to the appropriate journal.

To show which journals have published in certain research fields above or below the average amount, we calculated the corresponding differences to the average of the respective journal (compare Table 7). The European-based journal ISJ has the lowest total deviation from the respective average value; the value varies between -6% and +5 %. This broad thematic focus, without placing special focus on specific topics, has been mentioned by Avison and Fitzgerald (2012), who noted that the European-based ISJ is characterized by a methodological diversity and willingness to take on risky topics (Avison & Fitzgerald, 2012). A similar characteristic can be found for the MISQ. Again, the deviations are relatively small compared to the other journals. Other journals, such as the ISR, JIT, and JAIS, have other characteristics. ISR has placed an even greater focus on the research field “IS in Healthcare”, while JIT has focused on, for example, “Mobile Information Systems” and “Human Behavior & Cultural Aspects in IS”, and JAIS has focused on research fields such as “Contribution of Applied Science” and “IS in Organization & Society”. Of course, while it is not possible to characterize a journal only by the number of publications on a given research field, this information provides a valuable indication of the journal’s focus.

Table 7. Deviations from the respective average value

Deviations from the respective average value	EJIS	ISJ	ISR	JIT	JMIS	JAIS	MISQ	JSIS
Contribution of Applied Science	1%	1%	-1%	-6%	-4%	11%	1%	-3%
E-Business & E-Government	7%	1%	0%	2%	3%	-9%	-6%	3%
Funding of Innovations	-3%	-4%	2%	-5%	3%	-4%	2%	9%
Human Behavior & Cultural Aspects in IS	2%	5%	-4%	5%	-4%	-1%	-1%	-2%
Impacts of IT/IS	-3%	2%	-4%	3%	11%	-7%	-3%	-1%
IS in Healthcare	3%	-6%	13%	-6%	4%	-2%	-3%	-3%
IS in Organizations & Society	1%	1%	-3%	0%	-3%	4%	0%	0%
IS Research Methods & Philosophy	9%	3%	-3%	-3%	-5%	2%	-1%	-2%
IS Security & Privacy	-2%	-1%	1%	-8%	5%	3%	2%	0%
Knowledge Management	-3%	1%	-2%	3%	0%	-6%	3%	3%
Mobile Information Systems	-11%	-1%	4%	10%	-4%	2%	1%	0%
Service Science in IS	0%	0%	-2%	4%	-5%	3%	1%	0%
Social Media & Digital Collaboration	-1%	0%	-1%	1%	-1%	3%	5%	-4%

Note: Color coding for the percentage deviation of the number of publications from the average value: Red = Deviation down from the mean; Green = Deviation upwards from the mean.

Because thematic, paradigmatic, and geographical aspects are important when analyzing the development of a research domain (Avison et al., 2008, Stein et al., 2016), we also want to take a closer look at the development of IS research fields in different regions. In this context, we again used the four research fields “Social Media & Digital Collaboration”, “Impact of IT/IS”, “Service Science in IS”, and “Funding of Innovations”. However, the geographical assignment was not based on journals (e.g., EJIS, and ISJ – European-based and MISQ, ISR – North American-based); instead, the origin of the authors was used to make a corresponding geographical assignment of the publications to a specific region. As we can see in Figures 5a and 5b, there are regional differences in the development of the respective research fields. The research field “Impacts of IT/IS” developed differently regionally. While it has been relatively steady throughout North America and Europe with a slight increasing trend, in Asia, a relatively steep increase can be observed before the trend in YS3 starts to decline. Visible geographical trends in the second decade (YS3 and YS4) compared with the first (YS1 and YS2) include the strong rise of contributions from North America, Australia, and Asia concerning the research field “Social Media & Digital Collaboration”. Overall, the number of publications in all regions, except Europe, has risen sharply in this area. In Europe, there is also an increase in the second decade, but it is not as strong as in the other regions. These findings are in line with the conclusions drawn from Table 7: the number of publications in the research field “Social Media & Digital Collaboration” in European-based journals (e.g., EJIS and ISJ) is below the respective average value in terms of the proportions of journals in a research field. In contrast, this research field is more well represented in North American-based IS Journals (e.g., JAIS and MISQ).

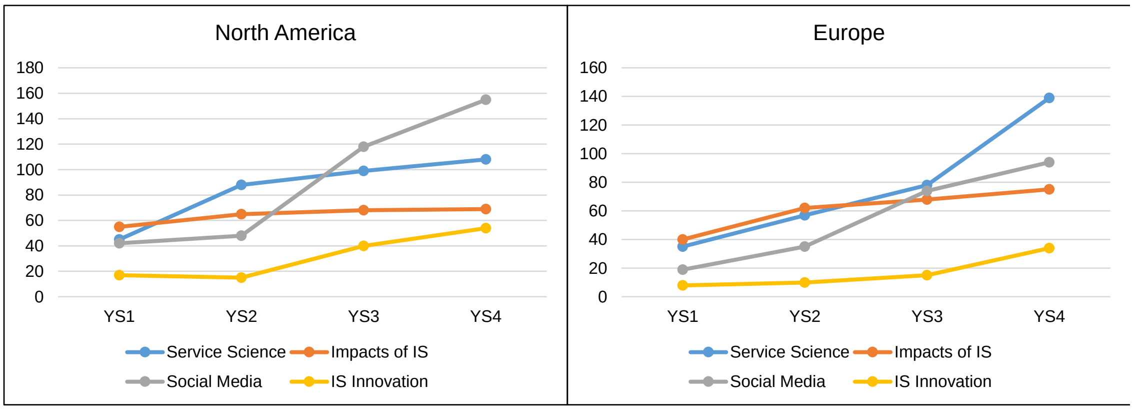

Figure 5a. Regional development of research fields – North America and Europe

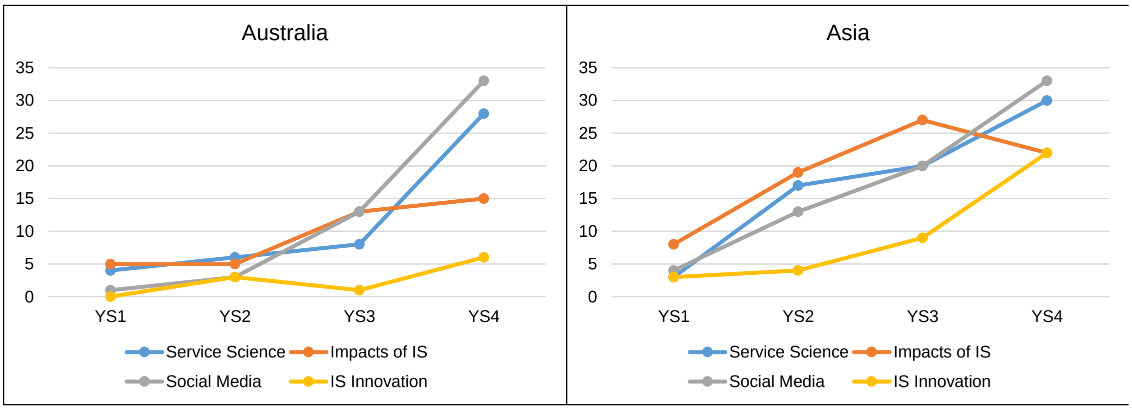

Figure 5b. Regional development of research fields – Australia and Asia

Discussion and Implications

As mentioned by Whitley and Galliers (2007), some researchers developed their research papers on, for example, the evolution and state of the IS research domain or citation classics by drawing on data in earlier studies (e.g., Walstrom & Leonard, 2000). Thus, there is a risk of path dependency because such studies normally had a tendency to analyze a limited set of ideas, approaches, and papers (Whitley & Galliers, 2007). We argue that the use of papers published in the AIS Bo8 and in ICIS proceedings, which represent the highest quality of research in the field (Lowry et al., 2013), provides a useful component for the presented longitudinal analysis because these data are less likely to suffer from problems of path dependency. The findings of our analysis, therefore provide a useful complement to existing studies (e.g., Goyal et al., 2018, Hassan & Mathiassen, 2018, Stein et al., 2016). Our study contributes to theory by following the commentary of Goyal et al. (2018, p. 413) and examining “a much broader set of journals such as the Senior Scholar’s basket of eight journals” to enhance the diversity. This was also mentioned by Sidorova et al. (2008), who noted that a comparative study of North American versus European IS research identities by including journals with a higher share of European publications could be an interesting direction for further research. By additionally drawing on conference papers rather than only journals, we are able to examine to what extent current trends in society are reflected in research.

Journal publications are not very well suited for this because of their sometimes very long publication times. Thus, conference proceedings may complement the analysis and provide a more up-to-date picture than can be found by analyzing journal articles alone (Whitley & Galliers, 2007).

The distribution of all publications speaks for itself. It should be noted that the majority of research contributions come from North American or European researchers. This finding is confirmed by studies by Avison et al. (2008), who analyzed publications within the journal ISJ. They called for more internalization and cited China, India, South America, and Africa, in particular, as countries that "are hotbeds of IS practice and becoming hotbeds of IS research" (Avison et al. 2008, p. 19). Looking at the distribution over the course of time, European research in the specific outlets has clearly adapted and caught up in terms of quantity. Lowry et al. (2007) criticize the under-representation of publications by non-North American researchers. Our results demonstrate a change in recent years. These developments have also been noted in general terms by Straub and Anderson (2010). During their investigations on MISQ, ISR, and EJIS from 2000 to 2009, they found a decrease in the publication numbers of American publications and a nearly doubling of European (and African) and of Asian and Australian publications. A decisive point for the future distribution is the number of published articles themselves. In the period under investigation, the number of ICIS publications more than tripled and almost doubled for AIS Bo8 publications. The only exception, with a decrease in published articles in this context, was the EJIS. The overall increase in publications as well as the increased interest over the past years has been identified by several authors (Buhl et al., 2012; Hassan & Mathiassen, 2018; Stein et al., 2016).

Ultimately, it is questionable to what extent continental publication volumes will develop in the future. Under certain circumstances, European research may gain further importance within these outlets under consideration, while publication numbers from the US may stagnate or even shrink. In contrast to Stein et al. (2016), who examined the development of European IS research based on ECIS, we did not find a leading position of the United Kingdom and Australia. However, we found an increase in the number of publications in Australia and Asia indicating that researchers from Australia and Asia may also experience an upswing in publication numbers. Despite this increasing internationalization of the IS research domain, it is still "disappointing that so few articles emanate from China and India" (Avison et al., 2008, p.19).

When considering journal-specific characteristics with regard to regional development, our study uncovered certain foci. While the EJIS, ISJ, and JIT have a more European focus, the majority of articles of the MISQ, JAIS, JMIS, and ISR are published by North American researchers. The JSIS was more North American at the beginning of the time periods considered here but has become a journal with a higher amount of European articles, which is interesting, because the JSIS is one of the four important European IS journals in the AIS Bo8 (Dwivedi & Kuljis, 2008). Galliers and Meadows (2003) stated in their article that there is a clear connection between the origin of the author and that of the journal. Lowry et al. (2004) found that North American researchers prefer more management-science- and decision-science-oriented journals and that European researchers, in contrast, are more interpretive and practice-relevant in their research. One reason for the increase in publications in the JSIS and the overall AIS Bo8 by European researchers in the last YS may be the different publication behavior in Europe as opposed to North America. The German-speaking research community (Germany, Austria, and Switzerland) is characterized by participation in industry projects according to the engineering tradition (Buhl et al., 2012) and has had a long-standing commitment to practice and business relevance (Stein et al., 2016). Despite this close link between research and practice, PhD students and junior faculty members (tenure track) are increasingly forced to publish in high-quality journals, especially while participating in doctoral or post-doctoral qualification program, and their guidelines are based on rankings. For example, the continuous increase of publications from German researchers can probably be explained by the A+ and A rating awarded to AIS Bo8 journals and ICIS papers by the Verband der Hochschullehrer für Betriebswirtschaft (VHB-JOURQUAL 3, 2015) (Stein et al., 2016). This development, which has emerged in the German-speaking IS community over the last 15 years, leads to increased publication pressure and research performance and suggests that German-speaking PhD students and junior faculty members are similar to North American researchers who are forced to publish in "elite" journals (Whitley & Galliers, 2007). This development was also observed in a study by Stein et al. (2016). They examined the trends in European IS research, especially in the ECIS, and noted a large increase in publications by German researchers. On the basis of our results, we could not find a similar development for the United Kingdom, thereby contradicting the study by Stein et al. (2016) who stated that the relative drop in yearly contributions at the ECIS "may well be because of the Research Assessment Exercise/Research Excellence Framework (RAE/REF) pressures to publish in leading journals as against conference proceedings" (Stein et al., 2016, p. 6). We could not confirm such a development because of a decrease in the number of publications from British researchers at the ECIS and the ICIS and in the AIS Bo8 journals. This is partially confirmed by the study by Avison et al. (2008), who noted that the number of publications from the United Kingdom in ISJ has dropped by half. The increasing pressure to compete internationally might be one reason for this development. Regions such as South America and Africa are still very rarely represented. This applies to publications in the AIS Bo8 journals as well as at conferences. Visible geographic trends in the fourth YS compared to the first YS include the rise of contributions from Asia in both the ICIS proceedings and the AIS Bo8 journals. An interesting issue here is that there is a significant increase in publications by Asian researchers in journals with a more North American tradition (e.g., MISQ, JMIS, JAIS, and ISR). In journals with a more European tradition (e.g., EJIS, ISJ, JSIS, and JIT), there are significantly fewer publications by Asian researchers and no significant increase in the number of publications.

The longitudinal analysis of papers published by the ICIS and in the AIS Bo8 journals also confirms a number of characteristics in the context of research fields considered both the European and the North American research tradition. For example, in their study of research published by the ECIS, Stein et al. (2016) show that IS organizational and strategic as well as systems development themes were the most popular. Another study by Dwivedi and Kuljis (2008), in which two European Journals – EJIS and ISJ – were compared showed that in both IS journals, the most popular research topics were related to IS development and IS management. Looking at the results of these two studies, the dynamics of our research domain are visible. If these results are supplemented by the results of our study, it becomes clear that in the further course of European IS research, research fields such as "IS Research Methods & Philosophy", "Human Behavior & Cultural Aspects in IS", and "E-Business & E-Government" have become relevant. E-government was also identified in a study by Mustafee (2011) as one of the relevant topics in the EJIS. The growth of papers on e-business and e-government is perhaps explained by the nature of IT and the growth of the Internet and the ongoing digital transformation (Palvia, 2007; Whitley & Galliers, 2007). The number of publications on these topics is significantly higher than the respective average value. More limited attention is given to specific technologies and the economic sector. This was also noted for the ECIS in a study by Stein et al. (2016) and suggests that even during times of the internationalization and dynamization of our research domain, not all characteristics of the European or North American research tradition have changed. As an example of a research field with a constant increase in the number of publications over time, the research field "Social media & Digital Collaboration" can be mentioned. There is a similar increase in publications in this research field both in AIS Bo8 and in the ICIS proceedings. The overall interest in this research field is also reflected in the total number of publications as well as in a distinct increasing trend with peaks in both the AIS Bo8 and the ICIS. The development of the IS research community and its research interests appear to be somewhat fluid and follow certain trends in society (e.g., Use of Twitter and Facebook). On the other hand, it can also be observed that topics that were of great interest in research at the end of the 1990s and the beginning of the 20th century are decreasing in terms of publication numbers at the ICIS and in the AIS Bo8 journals. This development, which represents the dynamics in our research domain, becomes very clear here. While knowledge management was considered a growing research field in the studies by Neufeld et al. (2007), Palvia (2007), and Lowry et al. (2007), we observed a decreasing trend here, with other research fields becoming increasingly important.

With this overview, we hope to provide scholars with sufficient information to identify the best outlet for reporting their research with regard to the thematic fit and, as mentioned by Stein et al. (2016, p. 12) “to prompt individual researchers to reflect on the motivation for their research and justifications for their future research plans”. A further implication is that knowledgeable researchers avoid unnecessary review cycles that occur when submitting research work to the wrong outlet (Dwivedi & Kuljis, 2008).

Limitations

One limitation is that we did not review all conference proceedings and journals in IS. For the database itself, which consisted of AIS Bo8 journals and ICIS proceeding publications, we focused on these outlets with regard to the classification and worldwide acceptance of the AIS. Certainly, there are journals at the top level and practitioner journals such as MISQ Executive (Palvia et al., 2015) that are not part of the focus of this research due to an evident regional focus or varying reputations. For conferences and journals such as, e.g., the Pacific Asia Conference on Information Systems (PACIS) and Scandinavian Conference on Information Systems (SCIS) the regional influence is obvious. These conferences and journals can be explored in the future to examine the evolution of the regions in our IS community that are not wholly attributable to either the European or the North American IS research tradition. However, by including all the AIS Bo8 journals as recommended by Goyal et al. (2018), we have covered a wide range of top IS research that is recognized in the global IS community.

Regarding database preparation, the varying data provisions by the different publishers of the AIS Bo8 journals and the ICIS proceedings resulted in several challenges. The automatic identification of the reference managing software was sometimes incorrect due to different metadata provisions, resulting in extensive manual postprocessing. Each publisher uses a different template and varying corresponding information. In outlets, where a Digital Object Identifier (DOI) was available, precise results were obtained. In cases with non-existent DOIs, we had to manually enter the metadata of each article because the journal sources are fragmented and the article layouts change over time, even if they are from the same source. Due to this extensive procedure, we cannot exclude some outliers despite a double check. Further limitations resulted from automatic country detection. Our developed algorithm was used to identify the origin of articles by using the country suffix of e-mail addresses. Therefore, we limited the investigation only to the corresponding author. However, this procedure is common, as noted in the database preparation section. In future studies, this method could be extended by an author position method. In cases where a public e-mail provider was used or no corresponding e-mail address was provided, we had to manually determine the country of origin from the postal address. Due to different metadata and layout structures of the outlets, algorithms identifying the country, country code or zip code achieve unusable results in most instances. A further limitation on a related issue is that it was not possible to detect 57 of 6,692 articles with regard to the author’s origin, although this represented less than one percent of the overall database.

Conclusions

In the sense of cumulative research, we have expanded existing research on the understanding of the profile of IS research. This is useful because continual introspection helps any research domain as it thrives and matures (Palvia, 2007). Although recent studies have mentioned that there are differences in terms of the development of the IS research domain, academic research has not properly considered the role of geographical aspects and topic emergence and has not taken into account various outlets, particularly the differences between publications in conference proceedings and journals. To shed light on this, we aimed to answer the following research questions: What is the regional distribution of publications in the AIS Bo8 and the ICIS? How has publication behavior changed by region, and what are the greatest changes? Finally, where - in terms of outlet and region - do IS research topics and trends emerge, and how have these changed over time? Our study offers contributions valuable for the IS community and its goal of developing an impact on research and society. First, in this longitudinal study, we investigated publications of top IS research outlets (all AIS Bo8 journals and the ICIS proceedings) in terms of geographical and periodical evolution over a period of 16 years. With the help of a semi-automated database, we were able to handle a large number of articles. Through the use of an algorithm to identify geographical emergence and a developed LSI tool, we established the foundation for our investigation. Based on the results of our analysis of 6,692 papers, we were able to identify differences in terms of the development of research topics in general and, particular, differences in the geographical context as well as the choice of outlet. This effort provides in-depth insights into the overall landscape of IS publications and the emerging body of IS-specific knowledge. Prospective authors also benefit from our work because it provides a good overview of our relatively young research domain and its growth and development.

References

AIS (2019a). About IS History. Retrieved September 1, 2019, from https://history.aisnet.org/

AIS (2019b). Advanced Search. Retrieved June 12, 2019, from https://aisel.aisnet.org/do/search/advanced/?fq=virtual_ancestor_link:%22https://aisel.aisnet.org
%22

Avison, D., Dwivedi, Y. K., Fitzgerald, G., & Powell, P. (2008). The beginnings of a new era: Time to reflect on 17 years of the ISJ. *Information Systems Journal, 18*(1), 5-21.

Avison, D., & Fitzgerald, G. (2012). Reflections and opinions on 25 years with the ISJ. *Information Systems Journal, 22*(3), 179-193.

Bandara, W., Furtmueller E., Gorbacheva E., Miskon, S., & Beekhuyzen (2015). Achieving rigor in literature reviews: Insights from qualitative data analysis and tool-support. *Communications of the Association for Information Systems, 37*, 154-204.

Barki, H., Rivard, S., & Talbot, J. (1993). A keyword classification scheme for IS research literature: An update. *MIS Quarterly, 17*(2), 209-226.

Bjørn-Andersen, N., & Clemmensen, T. (2017). The shaping of the Scandinavian socio-technical IS research tradition: confessions of an accomplice. *Scandinavian Journal of Information Systems, 29*(1), 79-118.

Börner, K. (2010). *Atlas of Science: Visualizing What We Know.* Cambridge, MA: MIT Press.

Buhl, H. U., Fridgen, G., König, W., Röglinger, M., & Wagner, C. (2012). Where's the competitive advantage in strategic Information Systems Research? Making the case for boundary-spanning research based on the German business and information systems engineering tradition. *Journal of Strategic Information Systems, 21*, 172-178.

Chen, W., & Hirschheim, R. (2004). A paradigmatic and methodological examination of Information Systems Research from 1991 to 2001. *Information Systems Journal, 14*(3), 197-235.

Chen, J., & Konstan, J. A. (2010). Conference paper selectivity and impact. *Communications of the ACM, 53*(6), 79-83.

Choi, J., Yi, S., & Lee, K. C. (2011). Analysis of keyword networks in MIS research and implications for predicting knowledge evolution. *Information & Management, 48*(8), 371-381.

Dwivedi, Y. K., & Kuljis, J. (2008). Profile of IS research published in the European Journal of Information Systems. *European Journal of Information Systems, 17*, 678-693.

Everard, A., Pierre, K. S., & Heck, J. L. (2017). Contributors to the high-impact IS journals (1977-2014): An aid for setting research standards. *Communications of the Association for Information Systems, 40*, 53-81.

Galliers, R. D., & Meadows, M. (2003). A discipline divided: Globalization and parochialism in Information Systems Research. *Communications of the Association for Information Systems, 11*, 108-117.

Galliers, R. D., & Whitley, E. A. (2007). Vive les differences?: Developing a profile of European Information Systems Research as a basis for international comparisons. *European Journal of Information Systems*, *16*(1), 20-35.

Goyal, S., Ahuja, M., & Guan, J. (2018). Information Systems Research themes: A seventeen-year data-driven temporal analysis. *Communications of the Association for Information Systems, 43*, 404-431.

Hassan, N. R. (2014). Value of IS research: Is there a crisis?. *Communications of the Association for Information Systems, 34*, 801-816.

Hassan, N. R., & Loebbecke, C. (2010). Engaging scientometrics in Information Systems: Combining the quantitative and qualitative. In *Proceedings of the International Conference on Information Systems*.

Hassan, N. R., & Mathiassen, L. (2018). Distilling a body of knowledge for Information Systems development. *Information Systems Research, 28*, 175-226.

Hirschheim, R., & Klein, H. K. (2012). A glorious and not-so-short history of the Information Systems field. *Journal of the Association for Information Systems, 13*(4), 188-235.

Hook, P., & Börner, K. (2005). Educational knowledge domain visualizations: Tools to navigate, understand, and internalize the structure of scholarly knowledge and expertise. In Spink, A., & Cole, C. (Eds.), *New Directions in Cognitive Information Retrieval* (pp. 187-208). Dordrecht: Springer.

Keen, P. G. W. (1980). MIS research: Reference disciplines and a cumulative tradition. In *Proceedings of the International Conference on Information Systems.*

Koukal, A., Gleue C., & Breitner, M. H. (2014). Enhancing literature review methods – Towards more efficient literature research with Latent Semantic Indexing. In *Proceedings of the European Conference on Information Systems*.

Lewis, B. R., Templeton, G. F., & Luo, X. (2007). A scientometric investigation into the validity of IS journal quality measures. *Journal of the Association for Information Systems, 8*(12), 619-633.

Loebbecke, C., & Leidner, D. (2012). The contribution of top IS publications to subsequent research: A citation analysis. *Communications of the Association for Information Systems*, *30*, 423-438.

Lowry, P., Romans, D., & Curtis, A. (2004). Global journal prestige and supporting disciplines: A scientometric study of Information Systems journals. *Journal of the Association for Information Systems, 5*(2), 29-77.

Lowry, P. B., Karuga, G. G., & Richardson, V. J. (2007). Assessing leading institutions, faculty, and articles in premier Information Systems research journals. *Communications of the Association for Information Systems, 20*, 142-203.

Lowry, P. B., Moody, G. D., & Gaskin, J. (2013). Evaluating journal quality and the Association for Information Systems (AIS) Senior Scholars' Journal Basket via bibliometric measures: Do expert journal assessments add value?. *MIS Quarterly, 37*(4), 993-1012.

Mustafee, N. (2011). Evolution of IS research based on literature published in two leading is journals – EJIS and MISQ. In *Proceedings of the European Conference on Information Systems.*

Neufeld, D., Fang, Y., & Huff, S. (2007) The IS identity crisis. *Communications of the Association for Information Systems, 19*, 447-464.

Palvia, P. (2007). A profile of Information Systems research published in Information & Management. *Information & Management, 44*, 1-11.

Palvia, P., Kakhki, M. D., Ghoshal, T., Uppala, V., & Wang, W. (2015). Methodological and topic trends in Information Systems research: A meta-analysis of IS journals. *Communications of the Association for Information Systems, 37*, 630-650.

Pouloudi, N., Poulymenakou, A., & Pramatari, K. (2012). A profile of information systems research in the Mediterranean region. *European Journal of Information Systems, 21*(4), 345-357.

Salton, G., Wong, A., & Yang, C.-S. (1975). A vector space model for automatic indexing. *Communications of the Association for Information Systems*, *18*, 613-620.

Schryen, G., Wagner, G., & Benlian, A. (2015). Theory of knowledge for literature reviews: An epistemological model, taxonomy and empirical analysis of IS literature. In *Proceedings of the International Conference on Information Systems.*

Serenko, A., Bontis, N., Booker, L., Sadeddin, K., & Hardie, T. (2009). A scientometric analysis of knowledge management and intellectual capital academic literature. *Journal of Knowledge Management, 14*(1), 3-23.

Sidorova, A., Evangelopoulos, N., Valacich, J. S., & Ramakrishan, T. (2008). Uncovering the intellectual core of the Information Systems discipline. *MIS Quarterly, 32*(3), 467-482.

Stein, M.-K., Galliers, R. D., & Whitley, E. A. (2016). Twenty years of the European information systems academy at ECIS: Emergent trends and research topics. *European Journal of Information Systems*, *25*, 1-15.

Straub, D. (2006). The value of scientometric studies: An introduction to a debate on IS as a reference discipline. *Journal of the Association for Information Systems, 25*(5), 1-15.

Straub, D., & Anderson, C. (2010). Authorship from 2000 through 2009. *MIS Quarterly, 34*(4), iii-vi.

Suomi, R. (1993). On the nationality balance of authors and references in selected MIS journals. *Information & Management, 24*(6), 339-347.

Te'eni, D. (2013). Journals and conferences in discourse. *European Journal of Information Systems*, *22*(6), 589-591.

Te'eni, D., Rowe, F., Ågerfalk, P. J., & Lee, J. S. (2015). Publishing and getting published in EJIS: Marshaling contributions for a diversity of genres. *European Journal of Information Systems, 24*(6), 559-568.

Vessey, I., Ramesh, V., & Glass, R. (2002). Research in Information Systems: An empirical study of diversity in the discipline and its journals. *Journal of Management Information Systems*, *19*(2), 129-174.

VHB-JOURQUAL 3 (2015). Teilranking Wirtschaftsinformatik & Informationsmanagement. Retrieved August 26, 2019, from https://vhbonline.org/vhb4you/jourqual/vhb-jourqual-3/teilrating-wi/

Wagner, G., Prester, J., & Schryen, G. (2017). Exploring the scientific impact of Information Systems Design Science Research: A scientometric study. In *Proceedings of the International Conference on Information Systems.*

Walstrom, K. A., & Leonard L. (2000). Citation classics from the information systems literature. *Information & Management, 38*(2), 59-72.

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly, 26*(2), xiii-xxiii.

Whitley, E. A., & Galliers, R. D. (2007). An alternative perspective on citation classics: Evidence from the first 10 years of the European Conference on Information Systems. *Information & Management, 44*, 441-455.

Appendix T: Behavioral Intention to Use Ridepooling Services - Empirical Insights and Recommendations

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Outlet: Transportation Research Part A

Abstract: Ridepooling is a new mobility service mainly for people in cities and urban areas. By matching the routes of customers with similar start and end points while driving in an optimally pooled manner, meaningful reductions in road traffic and related emissions can be achieved. Such services must meet customers' demands appropriately to achieve sustainable customer acceptance. Service providers face diverse customer expectations and prejudices that differ from those towards existing transportation modes. Today, most ridepooling trips are conducted with only one customer, confirming impressions of non-optimal operation. Using a survey-based approach, we analyzed possible relevant constructs for the acceptance of and intention to use ridepooling services. Using the technology acceptance model as the underlying framework, we performed partial least squares analysis with SmartPLS to investigate our dataset of 224 respondents. Our results suggest that perceived usefulness, perceived compatibility, and subjective norm have an influence on the behavioral intention to use ridepooling services. Our study expands the literature about the customer acceptance of ridepooling service as well as new mobility services in general. Further, we provide implications and recommendations for the development and implementation of the ridepooling concept for service providers.

Keywords: Ridepooling, Customer Acceptance, Technology Acceptance Model, Structural Equation Modeling.

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Introduction

Alongside the overall growth of the world's population, the share of people living in urban areas has been increasing rapidly and is expected to reach 66% by 2050 (United Nations, 2014). Due to people's needs for individual transport, this has led to an increased demand for mobility, especially in cities. The term *urban mobility* describes passenger movement within the city environment. Besides private vehicle ownership and public transport, people can choose *Mobility-as-a-Service* (MaaS), e.g., taxi, car-, or bikesharing to carry out their daily activities (Kamargianni and Matyas, 2017). Technological progress affects almost all aspects of human life, including the way people move. Emerging developments like digitalization, high-speed computing, location data, accurate sensors, wireless connectivity, social media expansion, and new pricing schemes have enabled so called *new mobility services* (NMS), a subcategory of MaaS (Spulber et al., 2016). The following NMS are relevant in this context. *Carsharing* involves users paying money based on the required time or distance when renting a car. *Ridesharing* (or *carpooling*) involves a private vehicle being shared by individuals traveling together from similar starting points to similar destinations, organized by an intermediary company or an informal system of users. *Ridehailing* involves, a passenger determining the trip's start and end point demanding a transport service offered by a professional or part-time driver. Finally, *ridepooling* (or *shared ridehailing or ridesplitting*) involves users hailing a shuttle to designated pick-up points near their location such that passengers with similar routes are matched and transported together in one vehicle (Clewlow and Mishra, 2017). As urban areas faced a multitude of traffic-related challenges such as high emissions, poor air quality, large traffic volumes, and constant congestion, NMS can contribute to a reduction in road traffic and its negative impacts (Chan and Shaheen, 2012). The total number of driving and parked vehicles can be reduced because the use of shared transportation partially substitutes private car ownership, consequently reducing traffic density, travel cost and time, fuel consumption per person, and air pollution (Furuhata et al., 2013; Kuntzsky et al., 2013).

Due to its economic, environmental, and societal advantages, ridepooling has a high potential for addressing the mobility needs of different target groups, but it is still scarcely used. Besides political and bureaucratic reasons (e.g., concessions and passenger transport laws), a notable barrier to general use appears to be the acceptance on and the ultimate usage by city dwellers themselves (Osswald et al., 2012; Sonneberg et al., 2019). For instance, the German provider *Berlkönig* had 410,000 users in the first six months of operation in Berlin (Jan–Jun 2019) with passenger pooling, achieved in 44% of the trips. As more than every second trip was undertaken by only one passenger, the demand was too low for appropriate pooling of users (Schwaer and Meyer, 2019). Regarding the environmental effect of ridepooling, one critical factor is the mode of transport the ridepooling customers usually use. In American cities, Schaller (2018) states that most users switch from non-car modes to shared rides, increasing overall vehicle mileage. Further, licensed drivers must wait for upcoming dispatches and navigate to pick-up locations without transporting passengers (Schaller, 2018). These circumstances demonstrate that the theoretical benefits of ridepooling can only be achieved if the usage is sufficiently high and there is a large demand. It would be ideal for those who otherwise drive their own cars to switch to ridepooling. As the profitability of ridepooling providers depends on appropriate supply and user demand, customer acceptance is crucial for the long-term success of the service.

In the literature, the acceptance of innovations has been investigated in various contexts (Karahanna et al., 2006). Quantitative studies have helped identifying the pertinent critical success factors (CSFs) for acceptance models. The most used and established model is the *technology acceptance model* (TAM) (Schierz et al., 2010). Sonneberg et al. (2019) investigated the acceptance of potential ridepooling customers in Germany, finding that perceived compatibility (PC) had the highest impact on (potential) customers' behavioral intention (BI) to use ridepooling services. However, as no other scientific studies focusing on the acceptance of potential ridepooling customers have been conducted so far, the field lacks further empirical evidence. We aimed to repeat and extend the study by Sonneberg et al. (2019) by investigating the constructs of environmental awareness (EA) and price value (PV) to allow for a more precise and sustainable understanding of the acceptance of ridepooling. EA and PV have been already investigated in other mobility contexts, and were described as significant for the acceptance of mobility services (e.g., Clewlow and Mishra, 2017; Wang et al., 2019). The study extends the scientific literature about the acceptance of ridepooling services and provides new insights by conducting the first repeated study of ridepooling acceptance. The results of both studies are compared and discussed. The conducted survey reveals important insights regarding the business model of ridepooling, providing implications and recommendations for ridepooling providers. The following research question (RQ) guided the research:

RQ: *Which constructs influence customers' ridepooling services acceptance, and which implications and recommendations can be drawn from the data for ridepooling providers?*

The paper is structured as follows. The second section provides a theoretical background of the TAM and presents a literature review on the acceptance of transportation services. In the third section we derive our underlying hypotheses, and our methodology is presented in the fourth section. The empirical analysis and results are presented in the fifth section. The sixth section contains further discussion as well as theoretical and practical implications and recommendations. In the seventh section, we reflect on the study's limitations and give indications for further research. In the eighth section, we conclude the paper.

Theoretical Background and Related Literature

Technology Acceptance Model

High acceptance of customers using an innovation or a technology is a CSF for long-term success of underlying business models. Following Schierz et al. (2010: 210), *acceptance* is defined as the "relatively enduring cognitive and affective perceptual orientation of an individual." The individual acceptance process depends on the interaction between effort and ultimate benefit (Davis, 1989). Investigations of the psychological processes underlying individual human behavior are complex and difficult, so several approaches have been developed to investigate individuals' technology acceptance and resulting usage (Ajzen, 1991; Madigan et al., 2017).

In the scientific literature, the TAM is the most cited model for investigating the acceptance of an innovation (Schierz et al., 2010). The TAM is an adaption of the *theory of reasoned action* (TRA), originally developed by Fishbein and Ajzen (1980) to predict human behavior. The TRA aims to explain and predict individual actions by assuming that people behave rationally and make use of all available information (Fishbein and Ajzen, 1980). Davis (1985) and Davis et al. (1989) adapted the ideas of the TRA to acceptance research in information system contexts and used it to explain the relationship between individuals' reaction to using a technology, their intention, and actual usage (Venkatesh et al., 2003). The TAM relies on BI to predict actual behavior and focuses on the identification of CSFs for adopting an innovation or technology (Taylor and Todd, 1995). Both the TAM and the TRA are based on individual beliefs, which determine attitudes towards a technology in a given situation (Giang et al., 2017). Beliefs are defined as "the person's subjective probability that performing the target behavior will result in salient consequence" (Davis, 1985: 16). These beliefs are internal psychological variables that function as mediators of all external variables, which may also affect the usage of an innovation (Agarwal and Prasad, 1999). Therefore, beliefs have an indirect effect on BI (Davis, 1985). In the TAM, beliefs consist of the two interacting factors of perceived usefulness (PU) and perceived ease of use (PEOU); in the TRA, attitude towards use (ATU) and subjective norm (SN) comprise beliefs (Wang et al., 2006). The TAM also covers the motivational variables that lead to actual system usage, reflecting a tendency that arises at the very beginning of contact with the innovation, which enables researchers to measure the acceptance of an innovation at an early stage (Davis, 1985). As the TAM was originally developed to predict technology use at workplaces, it can also be employed to predict customer behavior in other circumstances (Pavlou, 2003). For instance, the TAM has been applied to measure the customer acceptance of innovations such as internet banking, online shopping, or mobile services (Gefen et al., 2003; Cheng et al. 2006; Lee et al., 2009). Regarding innovations within the field of mobility, Osswald et al. (2010) investigated the acceptance of car information technology, Clewlow and Mishra (2017) and Wang et al. (2018) examined customers' ridehailing acceptance, and Herrenkind et al. (2019) and Lee et al. (2019) studied the acceptance of people travelling in autonomous vehicles.

Ridepooling

Ridepooling is a comparatively young mobility concept emerging in research. Ridepooling "has not apparently promoted transportation sustainability to date" (Merlin, 2019: 1), as in today's businesses very few people are matched and mileage is ultimately added to the city streets as most users switch from non-car modes of transport (Schaller, 2018; Schwaer and Meyer, 2019). However, with the right technology and a high number of customers, ridepooling could be a sustainable transport solution for urban areas (Merlin, 2019). Shaheen (2018) made a similar suggestion, pending the realization of key policy strategies such as operative privileges for parking, toll discounts for pooled vehicles, and rewards for customers, as well as the simplification of regulations of such services at the national level (Shaheen, 2018). Further, Sanguinetti et al. (2019) discussed the possibility of automated ridepooling vehicles and their implications in the future.

Focusing on the idea and operation of ridepooling, Gilibert and Ribas (2019) developed a shared ridehailing business model drawing upon the *Business Model Canvas* by Osterwalder et al. (2005). Based on a pilot project in Barcelona and a subsequent survey, several recommendations were given. First, ridepooling prices should not be more than double the cost of local public transport, and the service must be available, reliable, and safe at all times (Gilibert and Ribas, 2019). Further, exact information for the customers in terms of waiting and travel times as well as a partnership with local transport authorities and operators is crucial for long-term success (Gilibert and Ribas, 2019). König et al. (2018) reached a similar conclusion while conducting a survey using conjoint analysis to extract the service attributes of ridepooling customers. The relevant attributes were price, walking distance, time of booking, shift of departure time, travel time, and information provision (König et al., 2018). A significant influence in these attributes is the underlying assignment of customers to vehicles and resulting matched routes. In this regard, Alonso-Mora et al. (2017) presented a mathematical model for real-time ridepooling applications that dynamically generates optimal routes with respect to online demand and vehicle locations, validated on a public taxicab dataset in New York City. With approximately 22% of the existing taxis there, 3,000 pooling vehicles equipped with four seats could theoretically satisfy 98% of the total demand with minimal customer waiting times. Chen et al. (2017), Bischoff et al. (2018), and Yu et al. (2019) presented further approaches using different methods, allowing high capacity ridepooling to ensure efficiency and sustainability at the same time. Luo and Nie (2019) presented an optimization model for integrating ridepooling into existing mass transit systems. By comparing different scenarios with and without ridepooling, they concluded that ridepooling has only a limited impact on the scale effects of the network, but slight improvements to the accessibility of the network for overall system efficiency are possible.

In terms of user analysis and acceptance studies, limited research is available on ridepooling even though the long-term success of a ridepooling service depends heavily on customer acceptance. Several NMS were investigated by Spurlock et al. (2019), who found an adoption rate of 18% and an interest in adoption of a further 20% for ridepooling in an American context. Younger people and low to middle income earners were more open to it, giving positive ratings to the predicted cost advantages and reduced environmental impact of ridepooling (Spurlock et al., 2019). Further, Sonneberg et al. (2019) used the TAM to investigate the BI to use ridepooling services. In their German study, the strongest impact on such services was PC, while PS and PEOU were not relevant.

Hypothesis Generation

Attitude towards Use & Behavioral Intention to Use

For our study, we chose BI to use ridepooling services as one of our dependent variables for acceptance measuring. As described by Lee et al. (2003), actual systems usage is difficult to measure, especially for new services, which are in the beginning of implementation. This statement also holds for the rather new service of ridepooling (Sonneberg et al., 2019). However, actual systems usage can be approximated through BI, as several studies found in different contexts (Ajzen, 1991). ATU affects the BI to use services, because if people have a positive affect towards systems, intentions to perform behaviors arise (Davis et al., 1989). For example, Giang et al. (2017) examined the effects of the intention to adopt ridesharing applications in Vietnam, finding that ATU was a strong predictor of BI to use ridesharing services. In the case of ridepooling services, this leads us to the following hypothesis:
H1: ATU has a significant positive influence on the BI to use ridepooling services.

Perceived Usefulness

Usefulness is described as the subjective chance that using an information system will increase individual performance (Davis, 1989). PU can directly influence the BI to use services. In Davis et al. (1989), people perceived that they could increase their job performance by using specific information systems. In the case of on-demand car-related services, Kim et al. (2019) examined the positive effects of PU on ATU for such services. A higher usefulness of transportation services was perceived, with a higher degree of ATU resulting in BI to use. In accordance with Sonneberg et al. (2019), we propose the following hypotheses about the PU of ridepooling services:
H2: PU has a significant positive influence on ATU ridepooling services.
H3: PU has a significant positive influence on the BI to use ridepooling services.

Perceived Ease of Use

PEOU is described as users' expectation of how easy to use a system is (Davis et al., 1989). As described by Bandura (1977), ease of use influences behaviors due to self-efficiency beliefs, and easier performance of activities strengthens self-efficiency (Bandura, 1977). Previous work has assumed that PEOU influences the PU of services and innovations (Karahanna et al., 2006). Kim et al. (2019) found a positive influence of PEOU on ATU for on-demand car-related services. Based on these statements and findings, we propose the following hypotheses for PEOU in the context of ridepooling services:
H4: PEOU has a significant positive influence on ATU ridepooling services.
H5: PEOU has a significant positive influence on the PU of ridepooling services.

Perceived Compatibility

PC refers to the "degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters" (Lee et al., 2013: 761). Moore and Benbasat (1991) described PC as one of the core concepts in the acceptance of novel innovations. Kim et al. (2019) suggested that new on-demand transportations services must be compatible with and deliver the same experiences as traditional transportation services. Therefore, ridepooling services must also be coherent with the values and experiences of users regarding other services (Sonneberg et al., 2019). Based on these arguments and the results from prior studies, we build the following hypotheses on PC:
H6: PC has a significant positive influence on the PU of ridepooling services.
H7: PC has a significant positive influence on ATU ridepooling services.
H8: PC has a significant positive influence on the BI to use ridepooling services.

Perceived Safety

Osswald et al. (2012: 5) define perceived safety (PS) as "the degree to which an individual believes that using a system will affect his or her well-being." It is also described as the self-reflective perception of a situation as hazardous (Osswald et al., 2012). PS plays a decisive role in

transportation services, as a shared trip with unfamiliar drivers and other passengers is necessarily compared to other modes of transport (Chowdhury and Ceder, 2016). De Souza Silva et al. (2018) found that safety concerns are the main negative influence on the decision to use shared mobility services. Therefore, higher PS leads to higher acceptance. We examine this relationship of PS on ATU for ridepooling services with the following hypothesis:
H9: PS has a significant positive influence on the ATU ridepooling services.

Subjective Norm

SN refers to a compliance effect on BI from a social actor's (e.g., family member's) desire that a person behave in a specific manner (Venkatesh and Davis, 2000) under threat of punishment for non-action or promise of reward for good behavior (French and Raven, 1959). BI to use ridepooling services can in this way be influenced by social actors, like the family and friends of the user. In a ridesharing study in Vietnam, Giang et al. (2017) described a positive influence of SN on BI to use ridesharing services and the corresponding apps. If related people recommend using this service, user will have a BI to use them. Building upon this finding, we also propose SN as important for ridepooling services with the following hypothesis:
H10: SN has a significant positive influence on the BI to use ridepooling services.

Environmental Awareness

Kahn (2007) proposed a direct influence of a person's environmental ideology and ideas on their behaviors. In a more recent study, Chen and Hung (2016) suggested that high environmental knowledge is closely related to environmental behavior and awareness. Potential customers with a high EA prefer using green products and services (Bansal, 2011). Wang et al. (2019) found a significant positive relationship between EA and the BI to use ridesharing services. Therefore, insofar as ridepooling services aim to reduce emissions and traffic inside urban areas, such customers should value and use such services more highly, leading to the following hypothesis:
H11: EA has a significant positive influence on the BI to use ridepooling services.

Price Value

PV is defined as the "cognitive tradeoff between the perceived benefits of the applications and the monetary costs for using them" (Venkatesh et al., 2012: 161). Clewlow and Mishra (2017) revealed that the price of parking in cities is one of the most common reasons for using ridehailing services instead of personal driving. Chen et al. (2017) ascertained the significant influence of PV on transportation usage in a Chinese context. Most recently, König et al. (2018) noted the high relevance of fares in a ridepooling context with conjoint analysis. Consequently, the PV for mobility services plays an important role for the BI to use mobility services. Thus, customers of ridepooling services can also be influenced from their perceived PV on their BI to use such services. As result, we assume the following:
H12: PV has a significant positive influence on the BI to use ridepooling services.

Methodology and Data Collection

The research model and hypotheses were tested via data collection from an online survey conducted via the open-source survey software *LimeSurvey*. We distributed the questionnaire on social media pages like *Facebook* and *LinkedIn* as well as via e-mail through our transportation research network. Data collection took place from May 2019 to June 2019. Similar to Sonneberg et al. (2019), we presented a short introduction to the topic of ridepooling services in order to ensure similar levels of understanding of the service. Demographic information was collected regarding such aspects as age, gender, and usage of ridepooling services. Confidentiality and anonymity were guaranteed with a statement of the responsible usage of the data for research purposes (Chang et al., 2010; Podsakoff et al., 2003). This approach can *ex ante* reduce the probability of bias in participants' answers because of theory-in-use prejudices (Podsakoff et al., 2003; Chang et al., 2010).

All construct items were measured on a seven-point Likert scale ranging from "strongly disagree" (1) through "neutral" (neither disagree nor agree) (4) to "strongly agree" (7). Item scales for measuring the dependent and independent constructs were carefully designed based on existing scales used in different validated publications (Chang et al., 2010). We make use of the items from Sonneberg et al. (2019) for the constructs of ATU, BI, SN, PC, PEOU, PS, and PU, which were already adapted to the ridepooling context. Furthermore, we adapted the items for the construct of EA from Madigan et al. (2017) and PV from Venkatesh et al. (2012) to the ridepooling services context. We ensured content validity by asking colleagues and doctoral students to identify potential problems with the phrasings of the questions, reducing common method variance in the implementation of our questionnaire (Podsakoff et al., 2003). Due to only being distributed in Germany, all the questionnaire items were translated from their English sources into German, and the entire questionnaire was in German. We used back-translation techniques to avoid translation bias (Brislin, 1970). The underlying codebook with all items and sources can be found in the supplemental material.

From the survey, 311 datasets were collected. After identifying incomplete responses, 87 datasets were deleted. In total, 224 complete datasets were used for the analyses, representing a response rate of 72.03%. The descriptive statistics (Table 1) show a small majority of female respondents (126) over male respondents (98), and a majority of respondents (172) were between 20 and 29 years old. The participants were mainly students (157) with a monthly net income of less than 1,000 euros. The vast majority of respondents owned a driver's license (206), but only 123 had a car available. Most of the respondents lived in the city (144). With regard to ridepooling services, 124 respondents had already heard of them, whereas only 45 respondents had already used them. As potential reasons to use ridepooling services, the participants stated leisure activities (mentioned 93 times), travel to work (83), or travel to airports (127) (see Table 1 for all replies).

Question / Reply	Number	Percentage
What is your gender?		
Male	98	43.8
Female	126	56.3
Total	**224**	**100**
What is your age?		
20-29	172	76.8
30-39	27	12.1
40-49	6	2.7
50-59	6	2.7
≥ 60	1	0.4
No Information	12	5.4
Total	**224**	**100**
What is your monthly net income?		
< 1,000 €	68	30.4
< 1,500 €	33	14.7
< 2,000 €	19	8.5
< 2,500 €	22	9.8
< 3,000 €	15	6.7
≥ 3,000 €	40	17.9
No Information	27	12.1
Total	**224**	**100**
Question / Reply	**Number**	**Percentage**
Do you have a driver's license (car)?		
Yes	206	92.0
No	18	8.0
Total	**224**	**100**
Do you have a car for your own purposes available?		
Yes	123	54.9
No	101	45.1
Total	**224**	**100**
Which of the following describes your living environment the best?		
City	144	64.3
Countryside / Village	50	22.3
Suburbs	30	13.4
Total	**224**	**100**

What is your current occupation?		
Student	157	70.1
Worker	63	28.1
Other	4	1.8
Total	**224**	**100**
Have you ever heard of ridepooling services?		
Yes	124	55.4
No	100	44.6
Total	**224**	**100**
Have you already used ridepooling services?		
Yes	45	20.1
No	179	79.9
Total	**224**	**100**
For which purposes would you use ridepooling services? (multiple answers possible)		
Travel to airport	127	
Travel to nearest train station	102	
For leisure activities (e.g., visiting a bar)	93	
Travel to work	83	
Visiting friends and family	71	
Travel to university / school	59	
Travel for buying groceries	29	

Table 20. Descriptive Statistics

Empirical Analysis and Results

We performed partial least squares structural equation modeling (PLS-SEM) for our analysis. PLS-SEM is advantageous if the sample size is small, not normally distributed, or if the model is complex, with many estimated relationships (Hair et al., 2016). Compared with covariance-based SEM, PLS-SEM is more suitable for our purpose because of the simultaneous testing of the measurement and the structural model (Gefen et al., 2011). It is applicable in exploratory research, and it is preferred for measuring constructs with reflexive scales (Gefen et al., 2011; Xu et al., 2014; Hair et al., 2016). For our empirical analysis, we used the software package *SmartPLS* version 3.2.8 (Ringle et al. 2015). In line with Hair et al. (2016), a two-step approach was used, comprising measurement validation and model testing.

After recoding PS1 (which was a reverse item), we evaluated the reliability and validity of our measurement model by examining the factor loading of all items to the corresponding concepts. As suggested by Chin (1998), we included all items with a threshold value of 0.7 and higher to investigate indicator reliability, which means that at least 50% of the variance is shared with the corresponding construct. We excluded PC1, with a factor loading of 0.529, and SN4, with a factor loading of 0.311, from further analysis. The other factor loadings ranged from 0.643 (PS1) to 0.956 (SN1) (see supplemental material for all factor loadings). As the deletion of PS1, with a factor loading of 0.643, would not have led to an increase in composite reliability, it was retained for further analysis. We checked the constructs' Cronbach's alpha values, with 0.6 as the lower bound for internal consistency reliability (Hair et al., 2016). Our analysis found Cronbach's alpha values ranging from 0.674 (PS) to 0.938 (SN). All the composite reliability (CR) values of the constructs were over the threshold value of 0.7 as the upper bound for internal consistency reliability (Diamantopoulos et al., 2008; Hair et al., 2016). The average variance extracted (AVE) values were all above 0.5 (Hair et al., 2016), verifying the convergent validity of our data (see supplemental material). To check the discriminant validity of our dataset, we used the Fornell & Larcker criterion by comparing the square roots of the AVE values with the correlations between constructs (Fornell and Larcker, 1981). All of them were higher than the correlations between constructs (see Table 2).

Construct	Mean	SD.	CR	ATU	BI	SN	PC	PEOU	PS	PU	EA	PV
ATU	4.798	1.098	.909	**.816**								
BI	4.157	1.375	.926	.566	**.871**							
SN	4.537	1.170	.961	.517	.655	**.943**						
PC	4.560	1.101	.899	.570	.671	.617	**.904**					
PEOU	5.411	1.191	.950	.460	.338	.311	.407	**.909**				
PS	4.778	1.165	.822	.380	.356	.237	.318	.445	**.781**			
PU	4.446	1.201	.903	.706	.631	.521	.646	.385	.334	**.837**		
EA	4.789	1.430	.947	.199	.117	.122	.181	.175	.137	.237	**.903**	
PV	4.478	1.064	.946	.304	.399	.343	.364	.276	.215	.445	.212	**.924**

Table 21. Means, SDs, CRs, Square Roots of AVE, and Correlations between All Constructs

Due to ongoing critical discussion of the Fornell & Larcker criterion (e.g., Voorhees et al., 2016), we also investigated the heterotrait-monotrait ratio (HTMT) (Henseler et al., 2015), an estimate of the correlation between two constructs, with 1 indicating a lack of discriminant validity (Henseler et al., 2015). In our case, the confidence interval of the HTMT statistic was not 1 for any combinations of constructs, establishing discriminant validity. Table 2 above presents the means, standard deviations (SDs), CRs, square roots of AVE, and the correlations between all constructs. To analyze the structural model, we performed a bootstrapping procedure with 5,000 replications (Henseler et al., 2015), calculating the path coefficients and the coefficients of determination (adjusted R^2). Five of our 12 hypotheses were not significant (p-values ≥ 0.1), and seven were (p-value < 0.1). The significant path coefficients ranged from 0.14 (PU on BI) to 0.6 (PU on ATU). Concerning the endogenous variables, the adjusted R^2 was 0.43 for the construct of PU, 0.55 for ATU, and 0.63 for BI; thus, the model explains 43% of PU, 55% of ATU, and 63% of BI. All the results of our path analysis and bootstrapping procedure are visualized in Figure 1.

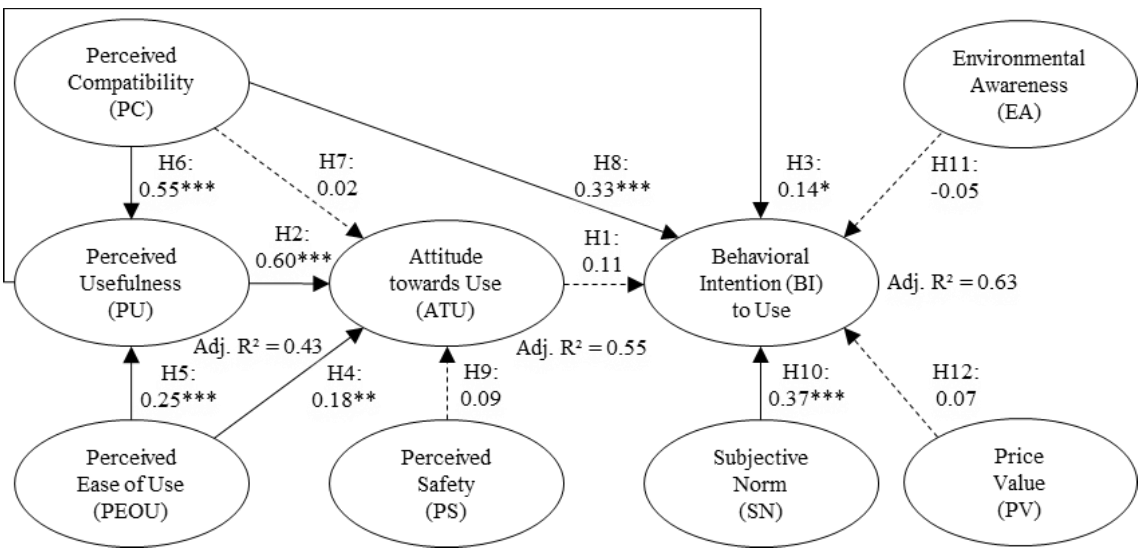

Figure 38. Results of the Bootstrapping Analysis for the Structural Model
*(Notes: *p < 0.1; **p < 0.01; ***p < 0.001; n = 224; dotted line represent insignificant paths)*

Finally, we checked the effect size (f^2) of the independent variables. Regardless of the sample size, f^2 can be used to compare different measured quantities to measure the impact of a predictor construct on independent variables (Hair et al., 2016). To evaluate whether the omitted constructs were meaningful to our research model, we made use of f^2-values as proposed by Cohen (1988), which show the influence of exogenous variables based on increased R^2 values that remain unexplained with respect to an endogenous construct (Peng and Lai, 2012). An f^2-value greater or equal to 0.35 indicates a large effect, values from 0.15 up to 0.35 represent a medium effect, and values between 0.02 and 0.15 indicate small effects (Cohen, 1988; Hair et al., 2016). According to Chin et al. (2003), a low f^2 does not indicate that the effect is not significant. Our calculated f^2-values are presented in Table 3.

Predictor Constructs	f^2	Effect Size
Attitude towards Use → Behavioral Intention to Use	0.017	Small
Perceived Usefulness → Attitude towards Use	0.437	Large
Perceived Compatibility → Behavioral Intention to Use	0.169	Medium
Perceived Ease of Use → Attitude towards Use	0.050	Small
Perceived Ease of Use → Perceived Usefulness	0.100	Small
Perceived Compatibility → Perceived Usefulness	0.485	Large
Perceived Compatibility → Attitude towards Use	0.001	Small
Perceived Compatibility → Behavioral Intention to Use	0.169	Medium
Perceived Safety → Attitude towards Use	0.012	Small
Subjective Norm → Behavioral Intention to Use	0.224	Medium
Environmental Awareness → Behavioral Intention to Use	0.007	Small
Price Value → Behavioral Intention to Use	0.009	Small

Table 22. Effect Size of Independent Variables (f^2)
Notes: Effect size f^2: ≥ 0.35 Large; ≥ 0.15 Medium; ≥ 0.02 Small;
f^2 = (R^2 included – R^2 excluded) / (1-R^2 included) (Cohen, 1988)

Discussion, Implications, and Recommendations

Our study analyzes the possible relevant constructs for the acceptance of ridepooling services. We structured this section according to the hypotheses, with a detailed discussion and analysis for each hypothesis, after which practical implications and recommendations are given. Finally, this section discusses the theoretical implications of the results.

Based on our results, we examined that ATU has no influence on the BI to use ridepooling services (H1), because it is slightly above the requisite significance levels (β = 0.11; p-value: 0.113). As this is one of the major relationships in the TAM, this result is rather surprising. Davis et al. (1989) stated that people's ATU for a service positively influences their behavior. As mentioned in the hypothesis generation section, Giang et al. (2017) determined that ATU was a strong predictor of BI to use ridesharing services. Our data do not support this relationship, indicating that customers' ATU for a service is not a prerequisite for BI to use that service. Yang and Yoo (2004) called for a more diverse analysis of attitude, with a separation of cognitive and affective ATU, finding that cognitive attitude has an influence on BI but affective attitude does not (Yang and Yoo, 2004). Perhaps, the construct ATU calls for a more differentiated measurement in the context of ridepooling services. Unlike our results, Sonneberg et al. (2019) found a strong effect of ATU on BI to use ridepooling services. Therefore, the measurement of ATU in ridepooling services may require continuous and more differentiated observation involving cognitive and affective attitudes separately (Yang and Yoo, 2004).

Consistent with Sonneberg et al. (2019), we found a high positive influence of PU on ATU (H2). In other words, higher PU of ridepooling services leads to a higher ATU for such services. We found the same relationship between PU and the BI to use (H3), in contrast to Sonneberg et al. (2019). Our findings confirm that PU is an important factor in both ATU and BI to use ridepooling services, as indicated by some research (e.g., Prekumar and Bhattacherjee, 2008). Therefore, to achieve continuous usage of ridepooling, providers must be aware about the PU of the customers and deliver a perceived usefully service.

In contrast to Sonneberg et al. (2019), we found that PEOU has a positive influence on the PU and ATU for ridepooling services (H4 and H5). We also cannot confirm Lee et al.'s (2003) partially identified doubtfulness of the construct of PEOU in the measurement of customer acceptance, but it is notable and worth discussing that two studies with identical interviews of identical subjects obtained partly different results regarding this construct. Our study is in line with

Giang et al. (2017), who found a positive relationship of PEOU an ATU in a ridesharing context. For ridepooling providers, this implies that, PEOU is an important predictor for usefulness and the attitude towards ridepooling. Only if customers perceive ridepooling services easy to use, they will perceive a usefulness of this service and build up an attitude towards such services. Therefore, providers must be aware of the benefits of a simple and clear booking process (e.g., through a mobile application) as well as an intuitive and easily understandable handling of the usage of the ridepooling service itself.

Next, we found that PC has an influence on PU and BI to use ridepooling services (H6 and H8), consistent with Sonneberg et al. (2019). In contrast to this study, however, we found no significant influence of PC on ATU (H7). Ridepooling services must be perceived as compatible to generate a BI to use and to be perceived as useful, being appropriate for the living conditions of the individual and delivering at least the same result as other transport services (Kim et al., 2019). Therefore, ridepooling services must provide a clear outcome for users, namely the transportation to a desired destination, and be useful in different life situations.

Based on our analysis, the construct of PS has no significant influence on ATU for ridepooling services (H9). In line with Sonneberg et al. (2019), we found that safety aspects are not relevant to the usage of ridepooling. Contrary to this, however, a study in the Brazilian market revealed a significant safety aspect in the context of ridehailing (de Souza Silva et al., 2018). Our German respondents seem to not be concerned with such aspects, so unfamiliar drivers or other passengers do not play a crucial role in their ATU for relevant transportation services.

We found a strong influence of SN on BI to use ridepooling services (H10), similar to the results of Sonneberg et al. (2019). This indicates that word of mouth and recommendations from social actors like family and friends are important in the adoption of ridepooling. As ridepooling is a new concept, early adopters articulate their feelings and opinions to others in their social networks. Early adopters play an important role in the diffusion of innovations, as late adopters tend to imitate them (Frattini et al., 2013). Therefore, ridepooling providers must be keenly aware of generating positive feelings about their service in early adopters due to their influence on late adopters and therefore new customers.

No significant influence of EA (H11) on the BI to use ridepooling services was found, in contrast to other researchers' findings in the NMS context (e.g., Wang et al., 2019). Our data indicates that customers' environment-friendly inclinations are not significantly associated with the use of ridepooling services. In contrast to our findings, Luo and Nie (2019) found slightly positive environmental aspects of ridepooling services, as they are used as a feeder service to public transportation stations. With a higher awareness that ridepooling can have positive effects on overall traffic performance, an environmentally friendly view of the service would be achieved, attracting more customers (Luo and Nie, 2019). This public relations measure could also attract customers using zero-emission vehicles (Shaheen, 2018). Based on our data, ridepooling providers must not highlight environmental aspects of their service. Due to these contradictory findings, a more detailed investigation of EA of ridepooling is necessary.

Further, we found no significant influence of PV (H12) on the BI to use ridepooling services. This is surprising, as other studies (e.g., Chen et al., 2017) have found that this construct is relevant in the transportation context. As can be seen from the descriptive statistics in Table 1, our respondents tend to use ridepooling for leisure activities rather than for regular transportation (e.g., commuting), leading to the assumption that ridepooling is a service for short and occasional rides, whereas ridesharing is used for longer trips between cities. Ridesharing services feature higher prices and are affected by the price pressures of other transportation modes, like trains. The majority of the respondents in our sample were students, who already have a discounted seasonal ticket for local transportation in the city, explaining why PV is not relevant to them for short and occasional trips. This explain why PV is not a necessary construct for the BI to use ridepooling services.

Overall, our results indicate a lower adjusted R^2 for the dependent variables (PU, ATU, and BI) than those in Sonneberg et al. (2019). There may be several reasons for this. Our sample differed from that of Sonneberg et al. (2019), as fewer respondents in our survey had knowledge of ridepooling services (55.4%, as shown in Table 1, vs. 67.0% (Sonneberg et al., 2019)). However, both studies had similar percentages of participants who had not previously used ridepooling (79.9% in our study, as shown in Table 1, vs. 79.0% in Sonneberg et al. (2019)). Further unknown variables that may be important for the acceptance of ridepooling services are missing in our model.

We mainly compared our results with those of Sonneberg et al. (2019) due to their theoretical contribution, expanding the limited literature about ridepooling. Moreover, our study is the first repeated study of a rather new mobility concept. Regular observation and analysis of the acceptance and diffusion of new concepts is crucial for, among other things, appropriate marketing activities (Peres et al., 2010). We also tested the TAM and evaluated further possible relevant constructs related to the BI to use such services. Despite this, our study was limited in certain ways and raises further pertinent questions, which we describe in the next section.

Limitations and Future Research Directions

One limitation of the study is the use of the TAM. Though it is a frequently used theory in the transportation context (e.g., Giang et al., 2017; Ruangkanjanases and Techapoolphol, 2018; Sonneberg et al., 2019; Wang et al., 2019), it is criticized for the over-simplicity of its constructs, such as PU (Benbasat and Barki, 2007). Though the TAM measures users' PU, it does not clarify which components of the new technology or service the customers perceive as useful or not. Other researchers have called for a more parsimonious usage of the TAM and more research on poorly understood constructs like PU (Straub and Burton-Jones, 2007). While one of the intentions of our study was to replicate and extend the study of Sonneberg et al. (2019), we would suggest the usage of more recent theoretical frameworks to measure customers' acceptance of ridepooling services, such as the unified theory of acceptance and use of technology 2 (UTAUT2) (Venkatesh et al., 2012) or combining the TAM with expectation disconfirmation theory (e.g., Prekumar and Bhattacherjee, 2008) as the underlying theoretical foundation. The usage of other theories may better identify the influences of moderation effects and lead to a better understanding of vague constructs like PU.

Most of our respondents had not used ridepooling services, and our dataset is restricted to mostly students in the age range of 20-29 (see Table 1). As ridepooling is a relatively new mobility concept, constant observation and analysis of CSFs for the acceptance of such services is crucial. Based on our results, the new constructs in our study (EA and PV) do not have a significant influence on the BI to use ridepooling services. However, for PV, other studies (see König et al., 2018) have implied that the price level plays a key role in using ridepooling services. Further research on a more diverse dataset with respondents from different age groups, occupations, and ridepooling experience is needed to clarify this. This could also indicate the influences of age-specific and cultural aspects on new service adoption.

As our study is only a static measure of the acceptance of ridepooling services, possible future research may consist in the continuous observation and analysis of the acceptance and success of ridepooling. As ridepooling is a relatively new mobility concept in Germany, it is not clear how the diffusion and adoption of the service will develop. Diffusion of innovations theory suggests that innovations spread through communication channels and social networks over time (Rogers, 1995). To examine the CSFs for the diffusion of ridepooling services, future research can use and expand the information systems diffusion variance model for quantitative studies, which is based on variables from the TAM (Cooper and Zmud, 1990; for an example in the motor carrier context, see Crum et al., 1996). Continuous observations and measurements of these aspects can lead to greater understanding for both service providers and scientists in this research area.

Conclusion

There has been a rapidly growing interest worldwide in NMS like ridepooling because they can lead to meaningful reductions of emissions and traffic in urban areas. Service providers face various expectations, customer prejudice, and low degrees of capacity utilization. To achieve long-term success, they must meet customers' demands appropriately and generate sustainable customer acceptance. Using a survey-based approach, we examined the possible relevant constructs for the acceptance of ridepooling services using the TAM as the underlying theoretical framework. We found that PU, PC, and SN have a significant positive influence on the BI to use ridepooling services. Our study expands the literature about service acceptance factors, indicating several implications and recommendations for ridepooling providers and enriching the ongoing academic and practical discussion on the acceptance and rationales of new mobility concepts like ridepooling.

References

1. Ajzen, I. (1991): The theory of planned behavior. *Organization Behavior and Human Decision Processes* 50(2), pp. 179-211. https://doi.org/10.1016/0749-5978(91)90020-T
2. Alonso-Mora, J., Samaranayake, S., Wallar, A., Frazzoli, E., Rus, D. (2017): On-demand high-capacity ride-sharing via dynamic trip-vehicle assignment. In: *Proceedings of the National Academy of Sciences* 114(3), pp. 462-467. https://doi.org/10.1073/pnas.1611675114
3. Bandura, A. (1977): Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review* 84(2), article 191.
4. Bansal, G. (2011): E-book usage: Role of environmental consciousness, personality and past usage. *Journal of Computer Information Systems* 52(2), pp. 93-104. https://doi.org/10.1080/08874417.2011.11645544
5. Benbasat, I., Barki, H. (2007): Quo vadis TAM? *Journal of the Association for Information Systems* 8(4), article 7.
6. Bischoff, J., Kaddoura, I., Maciejewski, M., Nagel, K. (2018): Simulation-based optimization of service areas for pooled ride-hailing operators. *Procedia Computer Science* 130, pp. 816-823. https://doi.org/10.1016/j.procs.2018.04.069
7. Brislin, R.W. (1970): Back-translation for cross-cultural research. *Journal of Cross-Cultural Psychology* 1(3), 185-216. https://doi.org/10.1177/135910457000100301
8. Chan, N.D., Shaheen, S.A. (2012): Ridesharing in North America: Past, present, and future. *Transportation Reviews* 32(1), pp. 93-112. https://doi.org/10.1080/01441647.2011.621557
9. Chang, S.J., Van Witteloostuijn, A., Eden, L. (2010): From the editors: Common method variance in international business research. *Journal of International Business Studies* 41(2), pp. 178-184. https://doi.org/10.1057/jibs.2009.88
10. Chen, S.C., Hung, C.W. (2016): Elucidating the factors influencing the acceptance of green products: An extension of theory of planned behavior. *Technological Forecasting and Social Change* 112, pp. 155-163. https://doi.org/10.1016/j.techfore.2016.08.022
11. Chen, Y., Salmanian, W., Akram, A. (2017): User acceptance in sharing economy - A study of transportation network companies in China. In: *Proceedings of the Mediterranean Conference on Information Systems*, article 24.
12. Chen, M.H., Jauhri, A., Shen, J.P. (2017): Data driven analysis of the potentials of dynamic ride pooling. In: *Proceedings of the ACM SIGSPATIAL Workshop on Computational Transportation Science*, pp. 7-12. https://doi.org/10.1145/3151547.3151549
13. Cheng, T.C.E., Lam, D.Y.C., Yeung, A.C.L. (2006): Adoption of internet banking: An empirical study in Hong Kong. *Decision Support Systems* 42(3), pp. 1558-1572. https://doi.org/10.1016/j.dss.2006.01.002
14. Chin, W.W. (1998): Issues and opinion on structural equation modeling. *Management Information Systems Research Quarterly* 29(3), pp. vii – xvi.
15. Chin, W.W., Marcolin, B.L., Newsted, P.R. (2003): A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Information Systems Research* 14(2), pp. 189-217. https://doi.org/10.1287/isre.14.2.189.16018

16. Chowdhury, S., Ceder, A.A. (2016): Users' willingness to ride an integrated public-transport service: A literature review. *Transport Policy* 48, pp. 183-195. https://doi.org/10.1016/j.tranpol.2016.03.007
17. Clewlow, R.R., Mishra, G.S. (2017): Disruptive transportation: The adoption, utilization, and impacts of ride-hailing in the United States. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-17-07.
18. Cohen, J. (1988): Statistical power analysis for the behavioral sciences. Abingdon, United Kingdom: Routledge
19. Cooper, R.B., Zmud, R.W. (1990): Information technology implementation research: A technological diffusion approach. *Management Science* 36(2), pp. 123-139. https://doi.org/10.1287/mnsc.36.2.123
20. Crum, M.R., Premkumar, G., Ramamurthy, K. (1996). An assessment of motor carrier adoption, use, and satisfaction with EDI. *Transportation Journal* 35(4), pp. 44-57. https://www.jstor.org/stable/20713289
21. Davis, F.D. (1985): A technology acceptance model for empirically testing new end-user information systems: Theory and results. Doctoral Dissertation, Cambridge, MA: Massachusetts Institute of Technology.
22. Davis, F.D. (1989): Perceived usefulness, perceived ease of use, and user acceptance of information technology. *Management Information Systems Research Quarterly* 13(3), pp. 319-340. https://doi.org/10.2307/249008
23. Davis, F.D., Bagozzi, R.P., Warshaw, P.R. (1989): User acceptance of computer technology: A comparison of two theoretical models. *Management Science* 35(8), pp. 982-1003. https://doi.org/10.1287/mnsc.35.8.982
24. de Souza Silva, L.A., de Andrade, M.O., Maia, M.L.A. (2018): How does the ride-hailing systems demand affect individual transport regulation? *Research in Transportation Economics* 69, pp. 600-606. https://doi.org/10.1016/j.retrec.2018.06.010
25. Diamantopoulos, A., Riefler, P., Roth, K.P. (2008): Advancing formative measurement models. *Journal of Business Research* 61(12), pp. 1203-1218. https://doi.org/10.1016/j.jbusres.2008.01.009
26. Doll, W.J., Hendrickson, A., Deng, X. (1994): Using Davis's perceived usefulness and ease-of-use instruments for decision making: A confirmatory and multigroup invariance analysis. *Decision Sciences* 29(4), pp. 839-869. https://doi.org/10.1111/j.1540-5915.1998.tb00879.x
27. Eggers, F., Eggers, F. (2011): Where have all the flowers gone? Forecasting green trends in the automobile industry with a choice-based conjoint adoption model. *Technological Forecasting and Social Change* 78(1), pp. 51-62. https://doi.org/10.1016/j.techfore.2010.06.014
28. Fishbein, M., Ajzen, I. (1980): Understanding attitudes and predicting social behavior. Upper Saddle River, New Jersey: Routledge.
29. Fornell, C., Larcker, D.F. (1981): Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research* 18(1), pp. 39-50. https://doi.org/10.1177/002224378101800104
30. Frattini, F., Bianchi, M., De Massis, A., Sikimic, U. (2014). The role of early adopters in the diffusion of new products: Differences between platform and nonplatform innovations. *Journal of Product Innovation Management* 31(3), pp. 466-488. https://doi.org/10.1111/jpim.12108
31. French, J.R.P., Raven, B. (1959): The bases of social power. In: Studies in Social Power, D.P. Cartwright (ed.), Ann Arbor, MI: Institute for Social Research, pp. 150-167.
32. Furuhata, M., Dessouky, M., Ordóñez, F., Brunet, M.E., Wang, X., König, S. (2013): Ridesharing: The state-of-the-art and future directions. *Transportation Research Part B* 57, pp. 28-46. https://doi.org/10.1016/j.trb.2013.08.012
33. Gefen, D., Karahanna, E., Straub, D.W. (2003): Trust and TAM in online shopping: An integrated model. *Management Information Systems Research Quarterly* 27(1), pp. 51-90. https://doi.org/10.2307/30036519
34. Gefen, D., Rigdon, E. E., Straub, D. (2011): Editor's comments: An update and extension to SEM guidelines for administrative and social science research. *Management Information Systems Research Quarterly* 35(2), pp. iii-xiv. https://doi.org/10.2307/23044042

35. Giang, P.T., Trang, P.T., Yen, V.T. (2017): An examination of factors influencing the intention to adopt ride-sharing applications. A case study in Vietnam. *Imperial Journal of Interdisciplinary Research* 3(10), pp. 618-623.
36. Gilibert Junyent, M., Ribas Vila, I. (2019): Main design factors for shared ride-hailing services from a user perspective. *International Journal of Transport Development and Integration* 3(3), pp. 195-206. http://dx.doi.org/10.2495/TDI-V3-N3-195-206
37. Hair Jr., J.F., Hult, G.T.M., Ringle, C., Sarstedt, M.J. (2016): A primer on partial least squares structural equation modeling (PLS-SEM). 2nd edition, Thousand Oaks, California: SAGE Publications.
38. Herrenkind, B., Brendel, A.B., Nastjuk, I., Greve, M., Kolbe, L.M. (2019): Investigating end-user acceptance of autonomous electric buses to accelerate diffusion. *Transportation Research Part D* 74, pp. 255-276. https://doi.org/10.1016/j.trd.2019.08.003
39. Henseler, J., Ringle, C.M., Sarstedt, M.J. (2015): A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science* 43(1), pp. 115-135. https://doi.org/10.1007/s11747-014-0403-8
40. Kahn, M.E. (2007): Do greens drive Hummers or hybrids? Environmental ideology as a determinant of consumer choice. *Journal of Environmental Economics and Management* 54(2), pp. 129-145. https://doi.org/10.1016/j.jeem.2007.05.001
41. Karahanna, E., Agarwal, R., Angst, C.M. (2006): Reconceptualizing compatibility beliefs in technology acceptance research. *Management Information Systems Research Quarterly* 30(4), pp. 781-804. https://doi.org/10.2307/25148754
42. Kamargianni, M., Matyas, M. (2017): The business ecosystem of mobility-as-a-service. In: Proceedings of the Annual Meeting of the Transportation Research Board, article 6538.
43. Kim, N., Park, Y., Lee, D. (2019): Differences in consumer intention to use on-demand automobile-related services in accordance with the degree of face-to-face interactions. *Technological Forecasting and Social Change* 139, pp. 277-286. https://doi.org/10.1016/j.techfore.2018.11.014
44. König, A., Bonus, T., Grippenkoven, J. (2018): Analyzing urban residents' appraisal of ride-pooling services attributes with conjoint analysis. *Sustainability* 10(10), article 3711. https://doi.org/10.3390/su10103711
45. Kuntzky, K., Wittke, S., Herrmann, C. (2013): Car and ride sharing concept as a product service system – Simulation as a tool to reduce environmental impacts. In: The philosopher's stone for sustainability, Y. Shimomura, K. Kimita (eds.), Berlin / Heidelberg, Deutschland: Springer, pp. 381-386. https://doi.org/10.1007/978-3-642-32847-3_64
46. Lee, M.-C. (2009): Factors influencing the adoption of internet banking: An integration of TAM and TPB with perceived risk and perceived benefit. *Electronic Commerce Research and Applications* 8(3), pp. 130-141. https://doi.org/10.1016/j.elerap.2008.11.006
47. Lee, Y., Kozar, K.A., Larsen, K.R. (2003): The technology acceptance model: Past, present, and future. *Communications of the Association for Information Systems* 12(1), article 50. https://doi.org/10.17705/1CAIS.01250
48. Lee, J., Lee, D., Park, Y., Lee, S., Ha, T. (2019): Autonomous vehicles can be shared, but a feeling of ownership is important: Examination of the influential factors for intention to use autonomous vehicles. *Transportation Research Part C* 107, pp. 411-422. https://doi.org/10.1016/j.trc.2019.08.020
49. Luo, S., Nie, Y.M. (2019): Impact of ride-pooling on the nature of transit network design. *Transportation Research Part B* 129, pp. 175-192. https://doi.org/10.1016/j.trb.2019.09.007
50. Madigan, R., Louw, T., Dziennus, M., Graindorge, T., Ortega, E., Graindorge, M., Merat, N. (2017): Acceptance of automated road transport systems: An adaptation of the UTAUT model. *Transportation Research Procedia* 14, pp. 2217-2226. https://doi.org/10.1016/j.trpro.2016.05.237
51. Merlin, L.A. (2019): Transportation sustainability follows from more people in fewer vehicles, not necessarily automation. *Journal of the American Planning Association* 85(4), pp. 501-510. https://doi.org/10.1080/01944363.2019.1637770

52. Moore, G.C., Benbasat, I. (1991): Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research* 2(3), pp. 192-222. https://doi.org/10.1287/isre.2.3.192
53. Osswald, S., Wurhofer, D., Trösterer, S., Beck, E., Tscheligi, M. (2012): Predicting information technology usage in the car: Towards a car technology acceptance model. In: *Proceedings of the International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, pp. 51-58. https://doi.org/10.1145/2390256.2390264
54. Osterwalder, A., Pigneur, Y., Tucci, C.L. (2005): Clarifying business models: Origins, present, and future of the concept. *Communications of the Association for Information Systems* 16, article 1. https://doi.org/10.17705/1CAIS.01601
55. Pavlou, P.A. (2003): Consumer acceptance of electronic commerce: Integrating trust and risk with the technology acceptance model. *International Journal of Electronic Commerce* 7(3), pp. 101-134. https://doi.org/10.1080/10864415.2003.11044275
56. Peng, D.X., Lai, F. (2012): Using partial least squares in operations management research: A practical guideline and summary of past research. *Journal of Operations Management* 30(6), pp. 467-480. https://doi.org/10.1016/j.jom.2012.06.002
57. Peres, R., Muller, E., Mahajan, V. (2010): Innovation diffusion and new product growth models: A critical review and research directions. *International Journal of Research in Marketing* 27(2), pp. 91-106. https://doi.org/10.1016/j.ijresmar.2009.12.012
58. Podsakoff, P.M., MacKenzie, S.B., Lee, L.-Y., Podsakoff, N.P. (2003): Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology* 88(5), pp. 879-903.
59. Premkumar, G., Bhattacherjee, A. (2008): Explaining information technology usage: A test of competing models. Omega, 36(1), pp. 64-75. https://doi.org/10.1016/j.omega.2005.12.002
60. Ringle, C.M., Wende, S., Becker, J.-M. (2015): SmartPLS 3. Boenningstedt, Germany: SmartPLS GmbH.
61. Rogers, E.M. (1995): Diffusion of Innovations. 4th edition, New York, NJ: Free Press.
62. Ruangkanjanases, A., Techapoolphol, C. (2018): Adoption of e-hailing applications: A comparative study between female and male users in Thailand. *Journal of Telecommunication, Electronic and Computer Engineering* 10, pp. 43-48.
63. Sanguinetti, A., Kurani, K., Ferguson, B. (2019): Is it ok to get in a car with a stranger? Risks and benefits of ride-pooling in shared automated vehicles. Institute of Transportation Studies, University of California, Davis, Research Report UC-ITS-2018-20. https://doi.org/10.7922/G27M064Z
64. Schaller, B. (2018): The new automobility: Lyft, Uber and the future of American cities. Avaiable online http://www.schallerconsult.com/rideservices/automobility.pd, accessed 21.11.2019.
65. Schierz, P.G., Schilke, O., Wirtz, B.W. (2010): Understanding consumer acceptance of mobile payment services: An empirical analysis. *Electronic Commerce Research and Applications* 9(3), pp. 209-216. https://doi.org/10.1016/j.elerap.2009.07.005
66. Schwaer, H., Meyer, C. (2019): Why ride-pooling providers in Germany have a hard time [in German: Warum sich ride-pooling-anbieter in Deutschland schwer tun]. Available online https://www.gruenderszene.de/business/ride-pooling-probleme, accessed 21.11.2019.
67. Shaheen, S. (2018): Shared mobility: The potential of ridehailing and pooling. In: Sperling, D., editor. *Three Revolutions.* Washington, D.C.: Island Press, pp. 55-76. https://doi.org/10.5822/978-1-61091-906-7_3
68. Spulber, A., Dennis, E.P., Wallace, R., Schultz, M. (2016): The impact of new mobility services on the automotive industry. Ann Arbor, MI: Center for Automotive Research.
69. Spurlock, C.A., Sears, J., Wong-Parodi, G., Walker, V., Jin, L., Taylor, M., Duvall, A., Gopal, A., Todd, A. (2019): Describing the users: Understanding adoption of and interest in shared, electrified, and automated transportation in the San Francisco Bay Area. *Transportation Research Part D* 71, pp. 283-301. https://doi.org/10.1016/j.trd.2019.01.014
70. Straub, D., Burton-Jones, A. (2007): Veni, vidi, vici: Breaking the TAM logjam. *Journal of the Association for Information Systems* 8(4), article 5. https://doi.org/10.17705/1jais.00124

71. Sonneberg, M.-O., Werth, O., Leyerer, M., Wille, W., Jarlik, M., Breitner, M.H. (2019): An empirical study of customers' behavioral intention to use RIDEPOOLING SERVICES - An extension of the technology acceptance model. In: *Proceedings of the International Conference on Wirtschaftsinformatik*, pp. 83-97.
72. Taylor, S., Todd, P.A. (1995): Understanding information technology usage: A test of competing models. *Information Systems Research* 6(2), pp. 144-176. https://doi.org/10.1287/isre.6.2.144
73. United Nations (2014): 2014 revision of the world urbanization prospects. Available online https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html, accessed 19.11.2019.
74. Venkatesh, V., Davis, F.D. (2000): A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science* 46(2), pp. 186-204. https://doi.org/10.1287/mnsc.46.2.186.11926
75. Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D.(2003): User acceptance of information technology: Toward a unified view. *Management Information Systems Research Quarterly* 27(3), pp. 425-478. https://doi.org/10.2307/30036540
76. Venkatesh, V., Thong, J.Y.L., Xu, X. (2012): Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *Management Information Systems Research Quarterly* 36(1), pp. 157-178. https://doi.org/10.2307/41410412
77. Voorhees, C.M., Brady, M.K., Calantone, R., Ramirez, E. (2016): Discriminant validity testing in marketing: An analysis, causes for concern, and proposed remedies. *Journal of the Academy of Marketing Science* 44(1), pp. 119-134. https://doi.org/10.1007/s11747-015-0455-4
78. Wang, Y.S., Lin, H.H., Luarn, P. (2006): Predicting consumer intention to use mobile service. *Information Systems Journal* 16(2), pp. 157-179. https://doi.org/10.1111/j.1365-2575.2006.00213.x
79. Wang, Y., Wang, S., Wang, J., Wei, J., Wang, C. (2018): An empirical study of consumers' intention to use ride-sharing services: Using an extended technology acceptance model. *Transportation* (in press, online first). https://doi.org/10.1007/s11116-018-9893-4
80. Xu, J.D., Benbasat, I., Cenfetelli, R.T. (2014): The nature and consequences of trade-off transparency in the context of recommendation agents. *Management Information Systems Research Quarterly* 38(2), pp. 379-406.
81. Yang, H.-D., Yoo, Y. (2004): It's all about attitude: Revisiting the technology acceptance model. *Decision Support Systems* 38(1), pp. 19-31. https://doi.org/10.1016/S0167-9236(03)00062-9
82. Yu, X., Shen, S. (2019): An integrated decomposition and approximate dynamic programming approach for on-demand ride pooling. *IEEE Transactions on Intelligent Transportation Systems* (in press, online first). https://doi.org/10.1109/TITS.2019.2934423

Appendix U: Optimization of Station-based Carsharing Networks: Increasing Sustainability through Heterogeneous Fleets and Emission Control

Authors: Marc-Oliver Sonneberg, Kathrin Kühne, and Michael H. Breitner

Outlet: IWI Discussion Paper Series, 94, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.

Link: https://www.iwi.uni-hannover.de/fileadmin/iwi/Publikationen/DP/IWI_DP94_k.pdf

Abstract: The positioning and dimensioning of carsharing stations have already been addressed in several optimization models applying homogeneous fleets. Yet, carsharing organizations increasingly apply mixed fleets of vehicles with different propulsion methods. We introduce a model, which permits a combination of differently powered vehicles and the option to include fleet emission constraints to satisfy customer expectations and governmental requirements. It supports decision makers in solving the challenge of fulfilling demands while maximizing profit. With an applicability check, the proposed model is evaluated. Extensive sensitivity analyses are presented and discussed indicating how a profitable operation of heterogeneous fleets can be established.

Keywords. Station-based Carsharing, Transportation, Network and Fleet Optimization, Sustainability.

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Appendix V: Shortening the Last Mile of E-Grocery: Optimizing a New Logistics Concept for Urban Areas

Authors: Max Leyerer, Marc-Oliver Sonneberg, Maximilian Heumann, and Michael H. Breitner

Outlet: Smart Cities, *Special Issue on Smart Cities and Data-driven Innovative Solutions*

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Abstract: Urbanization, the corresponding road traffic, and increasing e-grocery markets require efficient and at the same time eco-friendly transport solutions. In contrast to traditional food procurement at local grocery stores, e-grocery, i.e., online ordered goods, are transported directly to end customers. We develop and discuss an optimization approach to assist the planning of e-grocery deliveries in smart cities introducing a new last mile concept for the urban food supply chain. To supply city dwellers with their ordered products, a network of refrigerated grocery lockers is optimized to temporarily store the corresponding goods within urban areas. Customers either collect their orders by themselves or the products are delivered with electric cargo bicycles (ECBs). We propose a multi-echelon optimization model that minimizes the overall costs while consecutively determining optimal grocery locker locations, van routes from a depot to opened lockers, and ECB routes from lockers to customers. With our approach, we present an advanced concept for grocery deliveries in urban areas to shorten last mile distances, enhancing sustainable transportation by avoiding road traffic and emissions. Therefore, the concept is described as a smart transport system.

Keywords: E-Grocery, Last Mile Delivery, City Logistics, Sustainability, Location Routing Problem, Multi-echelon Optimization, Food Supply Chain.

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