Autonomous ground vehicles in urban last-mile delivery – an exploration of the implementation feasibility and consumer's acceptance

Daniel Barthuly

Dissertation written under the supervision of
Gonçalo Saraiva

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ABSTRACT

Title: Autonomous ground vehicles in urban last-mile delivery – an exploration of the implementation feasibility and consumer's acceptance
Author: Daniel Barthuly
Keywords: Service Innovation, Supply Chain Management, Last-mile delivery, Service Robotics, Autonomous vehicles, Technology acceptance model, Consumer acceptance, Human-robot acceptance

E-Commerce has rapidly changed the urban last-mile delivery in recent years, and Courier-, Express- and Parcel (CEP) companies are challenged by the increasing demand. Service robotics with autonomous vehicles are subject to be the catalyst for transforming the industry. Considering the infancy and lack of research on the subject, the purpose of this study is to explore the concept of autonomous ground vehicles (AGVs) in urban last-mile delivery from two perspectives.

First, data about the industry and insights from the technology provider summarize the status quo of recent developments and implementation barriers with the help of expert interviews. The findings show obstacles in the technological maturity and regulatory framework. Moreover, although only road-AGVs (rAGVs) will significantly change the industry, sidewalk-AGVs (sAGVs) act as a proof of concept as the implementation is more feasible. In addition, they create new premium services for the consumers.

Second, an attempt to determine the consumer's acceptance of sAGVs, using the combination of the technology acceptance model and the technology readiness index, is made with an online survey. The proposed research model is analysed by means of simple regression analysis, and all hypotheses are supported. The majority of the respondents have a positive attitude towards the concept of sAGVs for delivery and consider using it when the safety of their delivery goods is guaranteed.

This dissertation enriches the literature on human-robot acceptance as well as the management of CEP-companies to increase the engagement in the implementation of sidewalk-AGVs to increase service innovation for consumers.

SUMÁRIO

Título:	Veículos terrestres autónomos na entrega urbana de última milha – uma exploração da viabilidade de implementação e aceitação do consumidor
Autor:	Daniel Barthuly
Palavras-chave:	Inovação em Servicos, Logística integrada, Entrega urbana, Serviço de Robótica, veículos autónomos, Modelo de aceitação de tecnológica, Aceitação do consumidor, Aceitação Humano-Robô

O comércio electrónico mudou rapidamente a entrega urbana de bens ao consumidor, e as empresas de Correio Expresso Urgente são desafiadas pela procura crescente. Os serviços robóticos com veículos autónomos serão provavelmente o catalisador da transformação desta indústria. Considerando a falta e o estágio inicial de investigação, este estudo explora o conceito de veículos autónomos terrestres (AGVs) na entrega urbana de bens ao consumidor considerando duas perspetivas.

Uma primeira será a de recolher dados sobre a indústria e *insights* de fornecedores da tecnologia, sumarizando os mais recentes desenvolvimentos e as barreiras à implementação, com a ajuda de entrevistas a especialistas. Os resultados revelam obstáculos na maturidade tecnológica e enquadramento regulamentar. Adicionalmente, embora apenas os AGVs rodoviários (rAGVs) virão a alterar significativamente a indústria, os AGVs de passeio (sAGVs) atuam como prova de conceito, dada a sua implementação viável.

Em segundo lugar, a aceitação de sAGVs por parte do consumidor é determinada através da combinação de modelos de aceitação tecnológica e do índex de prontidão de tecnologia, via questionário *online*. O modelo de investigação proposto é testado por meio de análise de regressão simples, e todas as hipóteses são suportadas. A maioria dos participantes tem uma atitude positiva em relação aos sAGVs para entrega, e considera usá-los se a segurança dos seus bens for garantida.

Esta dissertação enriquece a literatura sobre aceitação humana-robot, bem como a gestão de empresas de Correio Expresso Urgente, aumentando o envolvimento na implementação de sAGVs e fomentando a inovação em serviços para o consumidor.

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AGV – Autonomous ground vehicles

AV – Autonomous vehicles

B2B – Business to Business

B2C – Business to Consumer

BIEK – Bundesverband Paket & Express Logistik

CEP – Courier -, Express - & Parcel

DPD – Dynamic Parcel Distribution

DPDHL – Deutsche Post DHL Group

GLS – General Logistics Services

GPS – Global Positioning System

IFR – International Federation of Robotics

INS – Inertial Navigation System

ISO – International Organization for Standardization

PeP – Post, e-commerce & Parcel

rAGV – road Autonomous Ground Vehicles

RPA – Robotic Process Automation

sAGV – sidewalk Autonomous Ground Vehicles

SC – Supply Chain

SCM – Supply Chain Management

TAM – Technology Acceptance Model

TRA – Theory of Reasoned Action

TRI – Technology Readiness Index

UAV – Unmanned Aerial Vehicles

UCC – Urban Consolidation Center

UGV – Unmanned Ground Vehicles

UPS – United Parcel Services

VRP – Vehicle Routing Problem

1. INTRODUCTION

1.1. Background & Problem Statement

In our fast-moving society, the lack of patience characterizes the digital consumer and results in the most dynamic environment in human history. The rise of e-commerce and changing consumer demands have affected the courier, express & parcel (CEP) industry largely in the last decade. Especially the last-mile, as the most inefficient part of the CEP-industry's supply chain, is identified as subject to change through new technologies.

New service innovation has increased the level of delivery services for consumers in terms of time and flexibility. Not only parcel tracking, next day delivery but also a growing infrastructure for parcel lockers have made the CEP-industry more dynamic.

New digital technologies have gained in complexity through the connection of multiple components and act as enablers of service innovation. One of the most advanced and controversial discipline is robotics, combining computer science and engineering, to solve very diverse industry challenges. Significant developments in artificial intelligence, sensors, big data, and cloud technology allow for new business opportunities in the service sector, which appeared highly futuristic a few years ago.

One application of service robotics is autonomous vehicles (AVs), primarily cars, which are inevitable in public discussions about future mobility. Research focuses on personal transportation, with the benefits in higher safety, reduced congestion, rising efficiency, but also freight transportation will be impacted (Litman, 2018). Despite the indisputable advantages, the implementation of AVs faces plenty of obstacles. Ethical considerations, missing regulatory frameworks and the economic scalability of the needed technologies are barriers for the commercialization. Already today, numerous autonomous operations in logistics warehouses can be observed, but are still not applicable for the open environment and the last- mile.

This dissertation focuses on the potential impact and business opportunity of autonomous ground vehicles (AGVs), currently being implemented or under development, in the urban last-mile delivery with a particular emphasis on the acceptance of consumers. Here, the CEP-industry is facing the question if AGVs can solve their efficiency challenges and how a potential implementation strategy could look like to be protected of disruption through new entrants.

1.2. Aim & Scope

The primary rationale of this dissertation is to understand how autonomous vehicles can alleviate the current urban last-mile delivery shortcomings, create new business opportunities and the role of the consumer within this development. To reach this goal the following research questions are addressed:

RQ1: How is the CEP-industry structured and what are its key activities?
RQ2: What are the key challenges in the urban last-mile delivery?
RQ3: What are the technological capabilities of AGVs for urban last-mile delivery?
RQ4: How can AGVs create opportunities and untie constraints in the urban last-mile delivery?
RQ5: Are consumers willing to accept and use AGVs for urban last-mile delivery?
RQ6: What are consumers differences in preferences for using AGVs for urban last-mile delivery?

1.3. Research Methods

This dissertation engaged in an exploratory research approach using both primary and secondary data. In the first place, desk research was conducted for the literature review, using secondary qualitative data about theoretical managerial concepts, the CEP-industry, and robotics. In this way, RQ1 and RQ2 were fully covered, whereas RQ3 and RQ4 gained the necessary groundwork to build upon in the primary research section. A combination of qualitative and quantitative data collection was chosen to supplement RQ3 and RQ4 with expert interviews, and address RQ4 to RQ6 to a wider audience with an online survey.

1.4. Relevance

This study provides both academic and managerial significance. The case of last-mile delivery is primarily covered in academic literature within the context of general routing problems to increase the efficiency of parcel delivery (Heilporn, Cordeau, & Laporte, 2010; McWilliams, Stanfield, & Geiger, 2005; Montreuil et al., 2018; Wang, Poikonen, & Golden, 2017). The case of AGVs in last-mile delivery is investigated by Boysen, Schwerdfeger, & Weidinger (2018) from a routing problem perspective. A few research papers exist within the area of consumer changing demands and the role of e-commerce in last-mile delivery (Li, Riley, & Hsieh, 2005; Seidel, Dablanc, Lenz, Blanquart, & Morganti, 2014).

Only Moroz & Polkowski (2016) and Vakulenko et al. (2018) looked into a specific concept in urban last-mile delivery to investigate the consumer's adoption potential.
Brynjolfsson & Mcafee (2014) describe the positive economic impact of replacing human tasks through several technologies for different industries and Wirtz et al. (2018) explore the role of robots in the future service industry. Xia & Yang (2017) present the current deployment state of AVs in China from an industry perspective and reveal challenges and opportunities. The feasibility of technological innovation is yet not the only prerequisite for a successful service innovation and in no case guarantees the consumer's acceptance. Broadbent, Stafford, & MacDonald (2009) are investigating the acceptance of healthcare robots among the older population, however, no research publication is available testing the potential consumer's acceptance of AGVs with a combination of the technology acceptance model and the technology readiness index.
The managerial relevance can be observed in the pilot projects of incumbent companies and the investment activity in technology startups with the main focus on AGVs for delivery (Table 2). Leading management consultancies investigate and publish reports on the future of last-mile delivery as a reaction of efficiency challenges in this industry (Bateman, Buhler, & Pharand, 2015; Heid, Neuhaus, Klink, & Tatomir, 2018; Joerss, Schröder, Neuhaus, Klink, & Mann, 2016).

1.5. Dissertation Outline

The dissertation is separated into five main chapters. The second chapter, the literature review, introduces a broad picture of the main concepts and research directions of value and supply chain management, as well as innovation management in services. Later, the main characteristics and structure of the German CEP-industry in relation to e-commerce will be presented. Further, the fundamental classifications of robotics and autonomous vehicles within the context of the future urban last-mile delivery are shown. The literature review concludes with the introduction of the used model to design the questionnaire and answer the respective hypotheses.
The third chapter outlines the research methodology, whereas the fourth presents the results of the data analysis in detail with a discussion at the end.
The final chapter concludes with an overview of the main findings. A recommendation for future research based on the underlying limitations will be given. A graphical overview is provided in Figure 1 to understand the chosen structure of this dissertation.

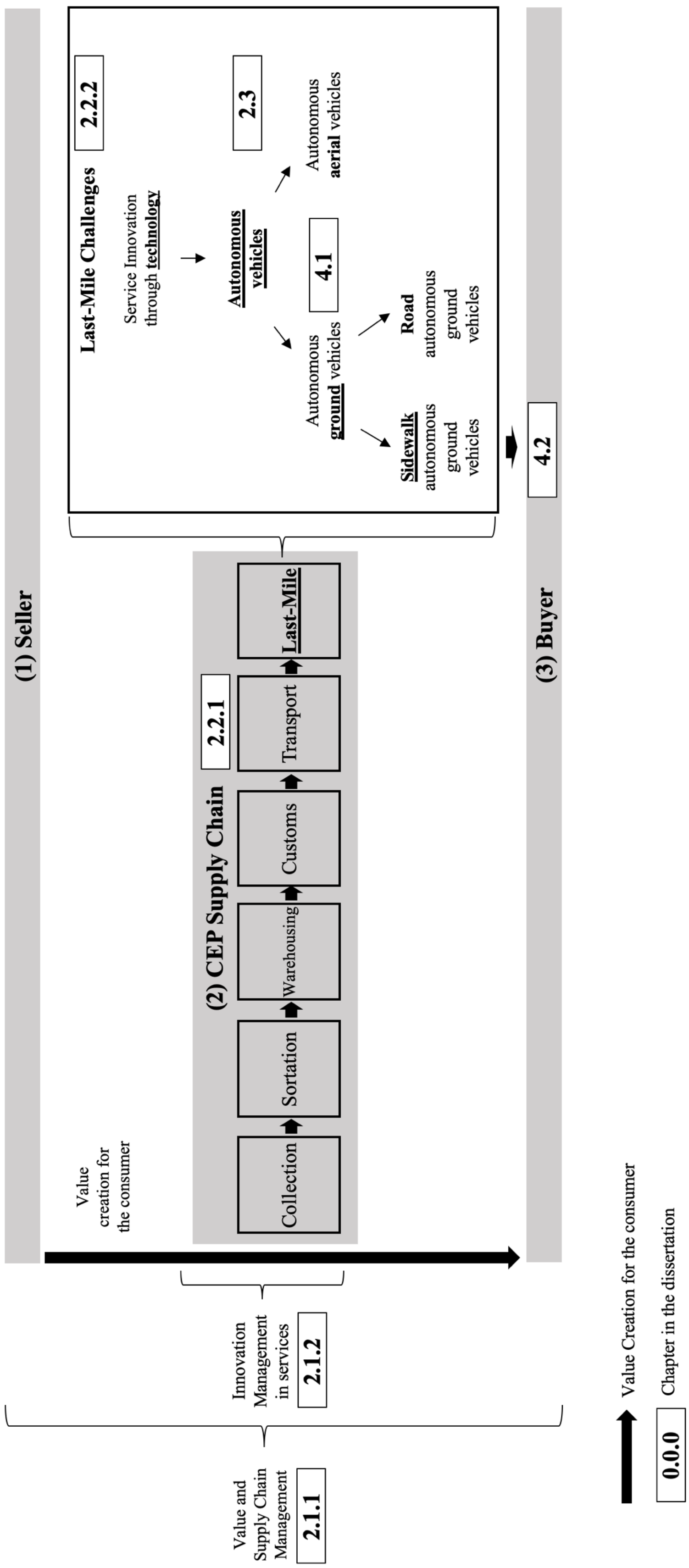


Figure 1: *Graphical overview of the dissertation structure*

2. LITERATURE REVIEW

2.1 Theoretical managerial foundation and classifications

In the following, the managerial roots of value chain (VC) and supply chain (SC), as well as innovation management in services will be touched briefly to understand the changing value creation for consumers and how the small part of the last-mile delivery is involved.

2.1.1 Value & Supply Chain Management (SCM)

Porter (1985) first proposed the concept of the VC in his work "Competitive advantage", after his first and most prominent publication, "Competitive strategy" of 1980, where he set the techniques for strategic planning of a company and the related industry analysis (Porter, 1985). The generic value chain is a firm level perspective and consists of two broad types of activities. Primary, or performing activities, describe the creation of the value for the customer and cover Inbound logistics, Operations, Outbound logistics, Marketing & Sales and Service. Secondary, or supporting activities facilitate the latter (Porter, 1985). The value is described as the customer's willingness to pay for the particular products and services, and the efficient execution of the activities along the chain determines the firm's profits and competitive advantage (Porter, 1985).

Closely related and first mentioned by logisticians Oliver and Webber in 1982 is the theory about SC (Harland, 1996). Already in the early days, several authors attempted to structure the existing work related to SCM (Bechtel & Jayaram, 1997; Cooper, Lambert, & Pagh, 1997; Harland, 1996). The traditional management approaches of VC & SC exist in a fundamental exchange relationship (Cox, 1997). The lack of a universal definition of SCM is a result of different points of views in the body of literature and is summarized by Croom, Romano, & Giannakis (2000). For this reason, Stock & Boyer (2009) performed an analysis of the prevalent definitions and suggested the following:

> "The management of a network of relationships within a firm and between interdependent organizations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction." (Stock & Boyer, 2009, p.706)

The remainder of this dissertation will include aspects of the suggested research areas by Stock, Boyer, & Harmon (2010) within the context of urban last-mile delivery and specifically touch on:

Add value: *Increasing profitability to organizations; Sustainability and environmental impacts of supply chains*
Create efficiencies: *Achieving cost minimization and optimization*
Increase customer service: *Achieving customer satisfaction*
Use of technologies: *Examining technology adoption and diffusion*

2.1.2 Innovation management in logistics services and the role of the consumer

According to Cooper et al. (1997), SCM is considered as an advancement of logistics management. As Mentzer, Esper, Stank, & Esper (2008) describe, logistics management evolved from a cost-management and efficiency driven part of the SC to a value-creating discipline and a source of competitive advantage. It is beyond the scope of this dissertation to explore the historical developments of logistics management (Kent & Flint, 1997, Mentzer et al., 2008, Sachan & Datta, 2005). The goal here is to emphasize the changes in recent years through technological innovation and the rising importance of the consumer's role in logistics management. Notably, the interface between the logistics provider and consumers is the main objective. Transportation, synonymously used for distribution management is customer-centric and can describe both, B2C and B2B customers (Gruchmann, 2019).
Klumpp & Heragu (2019) argue that transportation is of high importance as customer satisfaction and service quality are determined here. The customer focus became more relevant through the innovation in technology, especially with the birth of the internet in the late 1990s and accompanying e-commerce platforms.
The boom in e-commerce has drastically influenced and added complexity to both, SCM (Croom, 2005) and the nature of traditional distribution models, including delivery services directly to consumers (X2C).
Vice versa, with the changing economic drivers from manufacturing to services, also the innovation management literature started to gain focus on service innovation (Carlborg, Kindström, & Kowalkowski, 2014). Academic research shares the belief in the importance of innovation for business success but was mainly concerned about new product innovation through technologies. Sundbo (1997) pioneered the academic literature in service innovation, which can be separated in three distinctive phases, from a technology-centric, over a customer-centric to a multidimensional view (Carlborg et al., 2014).

In services, the sole focus on technological innovation is insufficient because of the important role of the customer (den Hertog, van der Aa, & de Jong, 2010). Chapman, Soosay, & Kandampully (2003) and Sundbo (1997) define the role of technology as the enabler for service innovation, resulting in value creation for the customer and a competitive advantage for the firm. In logistics management, service innovation can improve operational efficiency and better serve customers (Flint, Larsson, Gammelgaard, & Mentzer, 2005).

2.2 The rise of e-commerce and the effects on the CEP-industry

The rise of e-commerce paired with the liberalization of the markets resulted in tremendous effects for three main stakeholder groups and are presented in Figure 2. The group of (1) Seller comprises on the one hand (1.1) Pure-Play e-retailer, such as *Amazon*, and on the other hand (1.2) Bricks and Clicks seller, which are traditional retailer adding an online distribution channel, such as *Ikea*. The (2) CEP-industry serves as the intermediary between the seller and (3) the buyer, who can be either B2B or B2C. Buyer and consumer, as well as seller and e-retailer will be used interchangeably throughout.

The German market defines a suitable and dynamic environment for the following analysis with not only being the second biggest European market in e-commerce turnover but also locating the headquarter of *Deutsche Post DHL Group* (DPDHL), the world's biggest mail and logistics company. Logistics are increasingly important for e-retailers not only to provide a cost-benefit but also to differentiate themselves in service quality for deliveries.

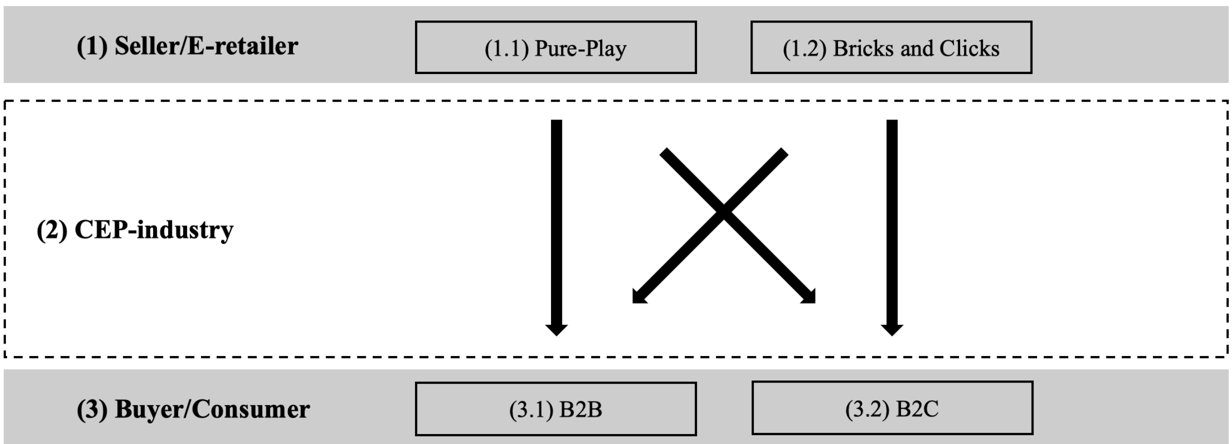


Figure 2: *Main stakeholders in any e-commerce transaction*

(own representation based on Agatz, Fleischmann, & Nunen (2008))

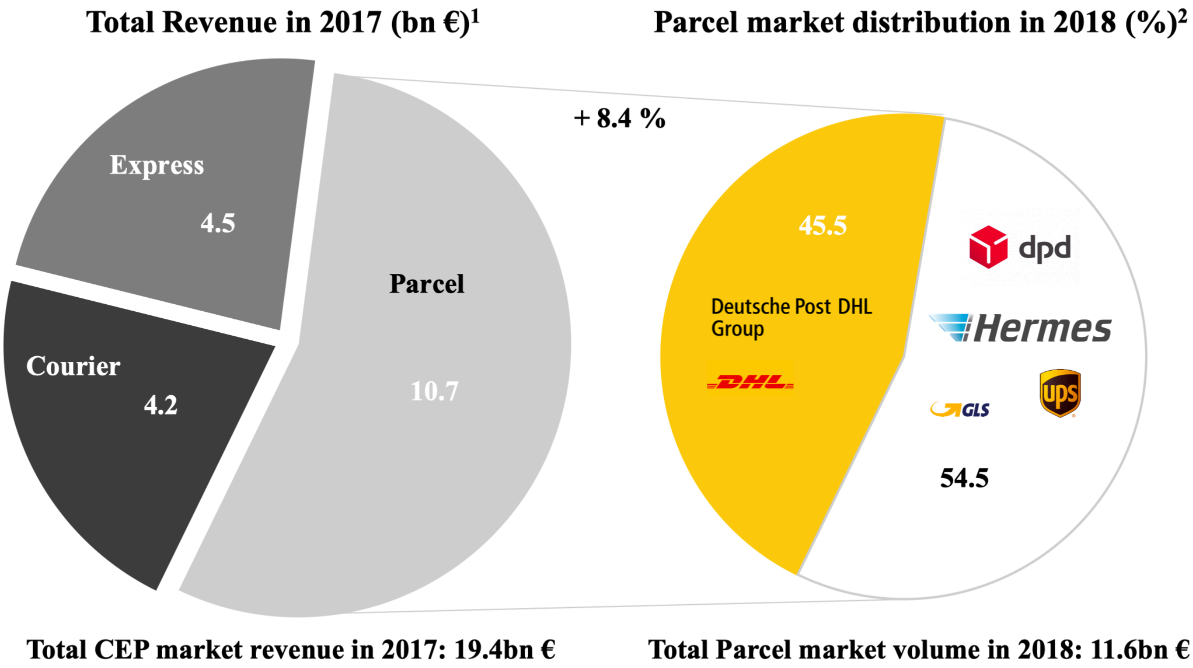
The literature agrees on the influence of logistics performance on a firm's profitability (Mentzer & Williams, 2001) and e-commerce even strengthened these findings (Rabinovich & Knemeyer, 2006). Chopra & Meindl (2007) stated the success of a company's SC is closely related to the appropriate use of transportation. Esper, Jensen, Turnipseed, & Burton (2003) show that consumers choice in e-commerce is dependent on logistics performance, especially the last-mile distribution. Ramanathan (2010) adds that the effect of logistics performance on customer loyalty is higher in e-commerce, compared to other industries.

As Agatz et al. (2008) describe, e-retailers need to manage, on the one hand, the necessary resources in terms of transportation and on the other hand, sustain a certain level of service quality. Accordingly, e-retailers are mostly outsourcing logistics services to the CEP-industry to meet consumer's demands.

2.2.1 The CEP-market in Germany

Logistics is the third largest economic sector in Germany (Grotemeier, 2018), and contributed 267.3bn € in revenue, of which 19.5bn € (7.2%) was generated by the CEP-market (Schwemmer, 2018). CEP-services vary in delivery time, price and reliability, but as a juridical definition is missing, only blurred lines exist between different offers. Manner-Romberg, Kille, & Müller-Steinfahrt (2015) characterize the **Courier service** by the shortest delivery time, either same day or agreed schedules; the **Express service** as time-definite delivery, depending on the geographical area, mostly over-night delivery; and the **Parcel service** as the least scheduled and flexible delivery method, without guaranteed time delivery windows. The standard delivery times in Germany vary between one and three days.

Figure 3 shows the dominance of the parcel segment within the CEP-markets with 55% (10.7bn €) in 2017. The CEP-industry report of BIEK (2018) forecasts an average growth rate of 5.2% each year until 2022. The Parcel market is the primary growth driver and follows an oligopolistic structure with five companies (Figure 3) competing for most of the market and differentiate in several aspects (See Appendix A).



[1]BIEK. (2018). KEP-Studie 2018 - Analyse des Marktes in Deutschland.
[2] Deutsche Post DHL Group. (2019). 2018 Annual Report.

Figure 3: *CEP-market revenues and distribution in Germany*

(own representation based on BIEK (2018) & Deutsche Post DHL Group (2019))

According to BIEK (2018), the CEP-industry provides 1% of all jobs in Germany and is the fastest growing of all economic sectors. This dynamic growth results in innovation challenges and internal changes as the shift of *DPDHL's* strategy from postal to parcel shows (See Appendix B).

The newly formed division, Post, e-Commerce and Parcel (PeP) generates together with Express 55% of *DPDHL's* annual revenue in 2017, and both segments face similar challenges due to the rise of e-commerce (Appendix B).

Not only the speed and increased volume of consignments, but also the variety of different products, aimed to be delivered to consumers, need to be handled. From 2013 to 2017, the e-commerce turnover in Germany increased from 54.9bn € to 85.6bn € and is forecasted to follow the trend with a growth rate of 8.6% for 2018 (Ecommerce Europe, 2018).

This results in a shift of business segments for the CEP-industry from B2B to B2C, as Figure 4 illustrates with the growth of the B2C share in turnover of 16% over eight years.

In addition, as international sales and cross-border deliveries gain in significance, even more volume and complexity are generated (Figure 4).

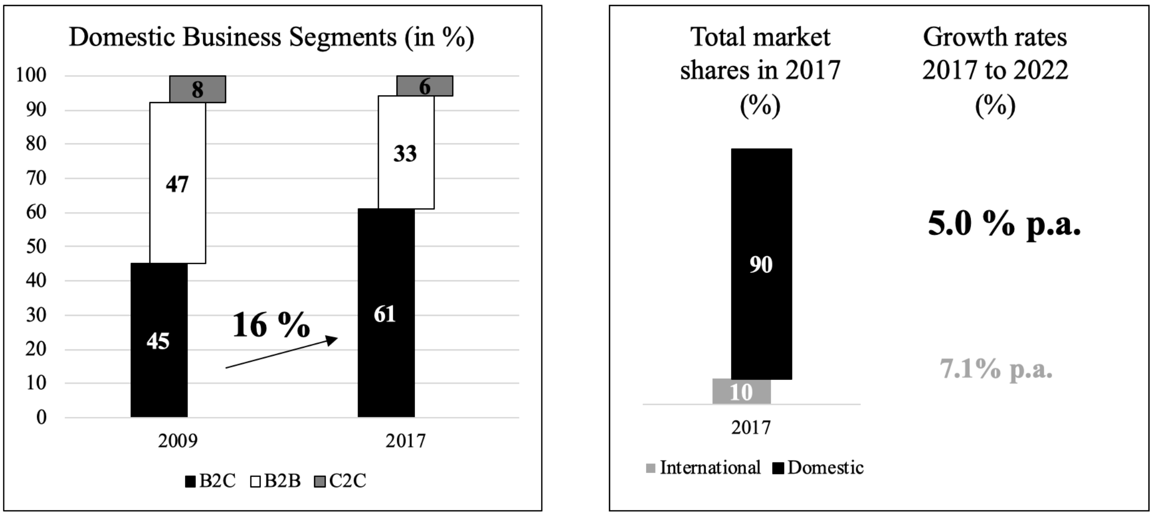


Figure 4: *German CEP-market by business segments and geographical focus*

(own representation based on (BIEK, 2018)

The speed of e-commerce sales forces the CEP-industry to redefine the parcel delivery supply chain and change from a reactive and efficiency driven industry to proactive service innovators. The typical supply chain of a parcel delivery company can be separated into six steps and is shown in Figure 5. Although innovation along all steps takes place for parcel delivery companies (Buhler & Pharand, 2019), the scope of this dissertation will focus on the analysis of the most challenging and dynamic step, the last-mile delivery.

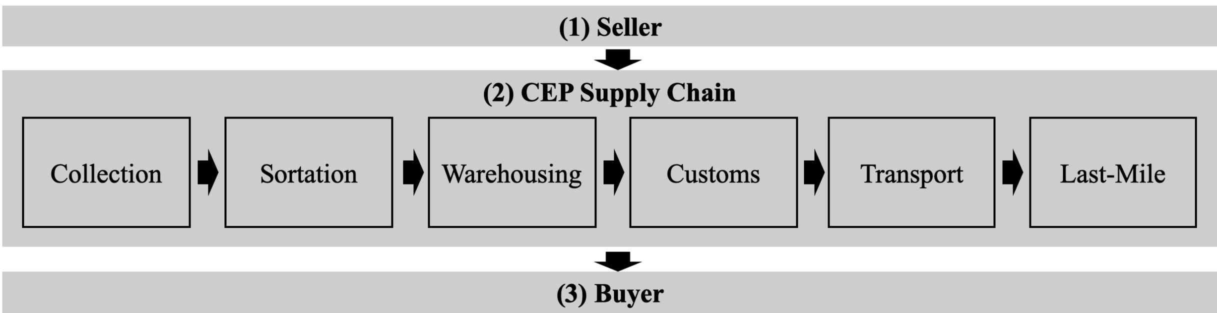


Figure 5: *Parcel delivery supply chain*

(own representation based on Buhler & Pharand (2019))

2.2.2 Key challenges in last-mile delivery and the role of consumers

The last-mile is typically the final stage in the parcel SC and involves a series of activities and processes necessary to deliver a parcel to the final drop point of the consumer, either the recipient's home or collection point (Esper et al., 2003; Gevaers, Van de Voorde, & Vanelslander, 2011; Heid et al., 2018; Yuen, Wang, Ng, & Wong, 2018).

The last-mile is considered as the most costly part of the delivery service with different estimations in literature. Gevaers et al. (2011) report a share between 13 to 75% of total logistics costs; Harrington, Singhai, Kumar, & Wohlrab (2016) state about 75% of total supply chain costs and Dolan (2018) estimates 53% of total costs of shipping. Urbanization, with today over 55% of the world's population living in urban areas (United Nations, 2018), has a catalytic effect on the efficiency challenges of last-mile delivery. Urban- or city-logistics are used synonymously for last-mile logistics in literature and are the focus in the remainder of this dissertation. Home deliveries are the leading cause for inefficiencies for distribution companies as the cost per parcels are higher when single units are ordered compared to one multiple unit delivery to physical stores (Esper et al., 2003). Two different perspectives (economic and social) on the challenges arise, which are interrelated but will be decoupled for illustrative purposes in Table 1 and complemented below.

Main causing factors	Urban last-mile challenges	
	ECONOMIC	
	Delivery Efficiency	Routing Problems Congestion
Technological innovation and the rise of e-commerce	***Maintaining Margins***	Cost structure
Increasing Urbanization		
	SOCIAL	
Liberalization of markets		
Globalisation	***Consumer Demands***	Speed Visibility Flexibility Reliability Costs Convenvience
	Environment	Pollution Safety Congestion

Table 1: *Key challenges of the urban last-mile and the corresponding causes*

(own representation)

Delivery Efficiency:

Delivery Efficiency is the operational practice to find the most efficient route for the delivery vehicle to decrease mileage in terms of time and distance (Gevaers, Van de Voorde, & Vanelslander, 2014). Many last-mile infrastructural designs are tested, including the optimal location of urban consolidation centers (UCC), where deliveries can be concentrated for urban delivery. Still, the routing problems consider the last-mile from a UCC to the consumer and as new services arise (e.g., in car trunk delivery or self-collection services) these algorithmic routing problems are increasing in dynamic variables, which complicates the delivery efficiency. There is a considerable body of literature for vehicle routing problems (VRP). Vehicle routing for in-car delivery (Reyes, Savelsbergh, & Toriello, 2017); routing problems with scheduled time windows (Heilporn et al., 2010) or the urban design of the parcel hub and network (Montreuil et al., 2018) only represent a few relevant research directions to improve delivery efficiency. One relevant variable in delivery efficiency is the increasing rate of congestion, due to the increasing density of traffic and transport in urban areas. As a result, the EU loses 1% of the EU's GDP because vehicles get stuck in traffic jams (Savelsbergh & Woensel, 2016).

Maintaining Margins:

The delivery efficiency drives the second challenge of maintaining margins (Eft, 2018). Heid et al. (2018) report labor costs as the biggest cost factor of last-mile delivery, and only 15% of total last-mile delivery costs origin from vehicle costs. In Germany, the hourly wage of employees in parcel delivery is regulated for *DPDHL*, but subcontractors are not obligated to these terms, which increases the competitive pressure on the incumbents. A juxtaposition can be observed between regulation authorities increasing the binding minimum wages, and consumers claiming for free delivery. This results in decreasing per unit revenue for the CEP-companies, from 6.22€ in 2007 to 5.78€ in 2017 (BIEK, 2018). Especially the likelihood of failed delivery as consumers are not encountered at home but a signature is required, increases delivery costs (Gevaers et al., 2011).

Consumer Demands:

Consumer demands change for the desire of speed with same-day and next-day delivery. Nevertheless, Joerss, Schröder, Neuhaus, Klink, & Mann (2016) stated that 70% of consumers still choose the cheapest delivery option, but 20 to 25% are willing to pay significant price premium (3€) to get same day delivery. Besides, 27% of respondents did not choose to shop online due to the long delivery times. Furthermore, consumers desire convenience in terms of home delivery. Self-collection services, including parcel stations and pickup shops, are not the preferred choice unless home delivery surpasses alternative delivery methods by 3€ (Joerss et al., 2016). Consumers ask for flexible deliveries (e.g. rescheduling) and shorter scheduled time-windows, as a result of more dynamic and unplanned lifestyles (Eft, 2018). Repeated home deliveries add another concern for CEP-companies, not only resulting in a lack of efficiency, but also tremendous impacts on the environment.

Environment:

As described above, congestion is one problem for efficiency but also impacts the environment negatively. Greenhouse gas emissions, as well as air and noise pollution are a result of both passenger and commercial vehicles. But, many of the commercial vehicle fleets are diesel-based for lower cost reasons, resulting in higher emissions. The European Commission (2016) reports transport as the leading cause of air pollution in cities and represents almost a quarter of Europe's total greenhouse gases. However, not only political pressure, but also brand reputation, incentivizes the CEP-companies to invest in electrical vehicles and alternative business models (Perboli & Rosano, 2019). Consumers' price sensitivity and rising demands, as well as new emerging business models through technological improvements offer new delivery services which are presented in the following section.

2.2.3 Last-mile-delivery opportunities

This section will describe the evolving opportunities used by both incumbent firms and new entrants to improve the current market situation. Heid et al. (2018) states the CEP-companies will remain very competitive in the foreseeable future market, because of high entry barriers. Thus, only very large e-retailers (e.g. *Amazon*) may enter the market with an integration of the last-mile delivery into their current business model. Currently, consumers can decide between traditional home delivery and collection services, which include pickup points of the respective retailers, post-office shops, or also parcel stations and lockers (See Appendix C). New business opportunities, as shown in

Figure ***6***, arise in three consecutive parts of the last-mile.

(1) Data analytics and advanced algorithms improve efficiency and service quality overall touchpoints. In specific, dynamic routing considers real-time traffic and consumer requests to modify delivery routes, algorithms help in smart planning with forecasting the demand, or sophisticated data enables a more precise tracking and visualization of the parcel for consumers, with the result of accurate arrival times (Lee, Chen, Gillai, & Rammohan, 2016).

The global trend of sharing economy also entered the last-mile via platform-based **(2) crowdsourced delivery**. Private passenger vehicles are being used to provide lower rates and faster delivery for all different kind of goods (Arslan, Agatz, Kroon, & Zuidwijk, 2018). New alternatives for self-collection with simply bigger private mailboxes for parcels, or public parcel stations, are already implemented. In car delivery, dynamic hand delivery, and smart door lock are pilot-tested and could reduce repeated deliveries (Bouton et al., 2017).

Although investments in electric vehicles are rising, is **(3) automation** suspected to be the most significant opportunity for the last-mile delivery with the potential to reduce urban delivery costs by approximately 10 to 40 percent (Heid et al., 2018). The results of a survey among supply chain and operations professionals conducted by Harrington & Smith (2017) show the relevance of robotics and autonomous vehicles as the highest ranked physical technologies in importance. Hence, the following section will analyze the current state of robotics in the last-mile delivery.

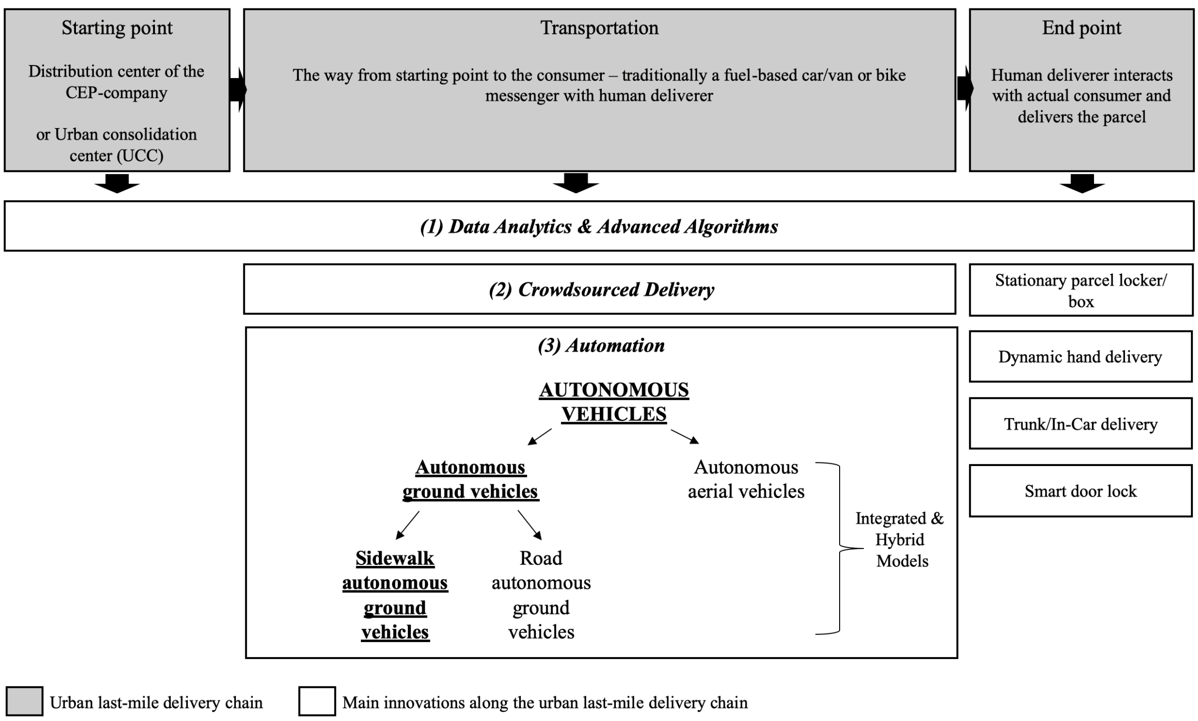


Figure 6: New business opportunities in last-mile delivery

(based on Bouton et al. (2017); Heid et al. (2018); Lee et al. (2016))

2.3 Technology Introduction: Robotics & Autonomous Vehicles

The International Federation of Robotics (IFR) reports a global turnover for robotics of $48bn in 2017 and the International Organization for Standardization (ISO) classifies robots into two categories (1) **industrial** and (2) **service robots.** ISO defines a robot as an actuated mechanism programmable in two or more axes with a (3) **degree of autonomy,** moving within its environment, to perform intended tasks (ISO, 2012; Litzenberger, 2018). Other researchers complement this classification with software robots, including robotic process automation (RPA) and social robots, specifically designed to interact with humans (Pieterson, Ebbers, & Madsen, 2017; Wagenmakers, 2016). Because this dissertation's focus will be on professional service robots and no standardized classification exists, IFR's definitions and market data will be used throughout.

(1) Industrial robots:

Automatically controlled, reprogrammable, multipurpose manipulator, programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications (ISO, 2012). In 2017, 381,000 units were sold and over 2 million industrial robots are in operation globally (IFR, 2018a). Industrial robots automate manufacturing in mainly the automotive and electronics industry with the highest numbers in shipment to Asia.

(2) Service robots:

Robots that perform useful tasks for humans or equipment excluding industrial automation applications (ISO, 2012). Service robots get more attention through media and emerging startups as they have a higher human-robot interaction.

(2.1) Personal service robots:

Despite growing numbers, service robots for personal use, account for a small fraction with $2.1bn in 2017, due to lower unit values and mainly include household robots (e.g. vacuum cleaners or toy robots) (IFR, 2018b).

(2.2) Professional service robots:

Sales figures for 2017 rose by 85% to 109,543 units with a value of $6.6bn, and the leading applications are in logistic systems (63%) and defense (11%) (IFR, 2018b). For the future, medical robots in assisting surgeries or therapy and exoskeleton robots in supporting rehabilitation are the most promising (IFR, 2018b). Logistics systems include automated guided vehicles in manufacturing environments, but also in non-manufacturing environments, including automation of e-commerce and logistics in hospitals. One example is the introduction of fully autonomous robots in warehouses, as seen by *Kiva* for *Amazon* (Mountz, 2012) or *Quicktron* for *Alibaba*, which tripled the output in a Chinese warehouse (You, 2017).

(3) Degree of autonomy:

Autonomy describes the ability to perform intended tasks based on current state and sensing, without human intervention (ISO, 2012). The Society of Automotive Engineers (SAE) introduced six levels of driving automation (level 0 to level 5) and updates them continuously. Examples illustrate the changes in the respective levels from no to full automation (See Appendix D). In this dissertation, a separation between semi- and full autonomy is sufficient. Semi-autonomous vehicles are accompanied by humans and will be the first step towards full autonomy in parcel delivery in the foreseeable future (Heid et al., 2018).

2.3.1 Autonomous vehicles in the last-mile delivery

Currently, AVs in last-mile delivery are separated into two categories, autonomous aerial vehicles and autonomous ground vehicles**.**

Autonomous aerial vehicles or unmanned aerial vehicles (UAV) in last-mile delivery are recently generating increased media attention. Electrically powered drones are mainly designed for a small average carrying capacity in rural areas within difficult terrain, as they offer a high advantage of speed and independence on road infrastructure (Lee et al., 2016). Companies working on drone delivery are diverse, including startups, incumbent CEP-companies (*DPDHL*, *UPS*), e-retailer (*Amazon*, *Alibaba*) or even *Boeing*, *Airbus*, and *Alphabet*. The design of drones and technological specifications differ for capacity and range reasons and are described by Xu (2017) in greater detail. Currently, drone delivery focuses on the transport of medical supplies, such as blood or vaccines, to isolated areas (Ackerman & Strickland, 2018; Glauser, 2018). In the future, instant or same day deliveries in urban areas become an attractive possibility for cost reasons.

The full autonomy level could cut costs of labor, as only monitoring and maintenance functions are necessary. Sudbury & Hutchinson (2016) calculate a cost saving per delivery of at least one third assuming a regular delivery at 1.20$ compared to a drone delivery of 0.36$. However, the calculations vary, as Lee et al. (2016) report a unit cost of 0.88$. But, obstacles for the implementation of drone delivery exist in governmental regulation (Jones, 2017), as well as in public concerns for safety and privacy (Lidynia, Philipsen, & Ziefle, 2017). The future projections among researchers state a strong industry interest in drone delivery but no commercial adoption in the near to medium term (Bouton et al., 2017; Lee et al., 2016).

Autonomous ground vehicles or unmanned ground vehicles (UGV) are prospected to be much closer to reality in last-mile delivery than aerial (Heid et al., 2018; Savelsbergh & Woensel, 2016).

Certainly, the level of autonomy plays a significant role in cost calculations, as seen in the drone setting. Semi-autonomous vans are electrical vans with a limited level of autonomy and are deployed at the moment. The benefit is small, as human deliverers are still necessary to bring the parcel to the door, and only the driving is supported. Yet, as human deliverers are increasingly overworked, especially in peak periods (e.g. Christmas), any relief is highly desired.

As presented in Figure 6 sidewalk AGVs and road AGVs can be separated but also autonomous parcel lockers are taken into consideration.

Autonomous parcel lockers could either park in the proximity of consumers for self-collection or even route the lockers from door-to-door (See Appendix E). The increasing numbers of permanent parcel locker installations in Germany show a reasonable alternative to home delivery, although self-collection services are slowly adopted, and home delivery is evidently preferred by the consumers (Joerss et al., 2016). The progression to autonomous parcel lockers would result in a delivery cost saving of 50% per unit from 1.75$ to 0.85$ (Bouton et al., 2017). Fully autonomous parcel lockers would increase the convenience for the consumers as they eliminate the need to walk to the next station. Likewise, they reduce space problems for fixed installations, which is primarily in dense urban areas of high importance. To date, only a few concepts are publicly announced of *DPDgroup* (2018) and *Next Transportation* (2018), but Bouton et al. (2017) see a high value in autonomous ground vehicle lockers for the future.

In general, a clear distinction between autonomous vans, lockers, and droids is not yet given. Nonetheless, a differentiation between the operational location and consequently the vehicle sizes allow for a classification. Figure 7 shows the fundamental distinction between sidewalk AGVs (sAGV), synonymously used for droids or bots, and road AGVs (rAGVs), which represent autonomous vehicles similar to cars and vans. The sAGVs are designed to manage local last-mile deliveries of different kinds of goods with a maximum weight of 10kg and a capacity for two shoe boxes (See Appendix F). At the moment, the robots deliver food and groceries within a 2-mile radius with a speed of 6 km/h (Starships Technologies, 2019).

Bouton et al. (2017) see sAGVs limited in application and impact for the delivery value chain but see the high value for consumers.

However, the most significant benefit of sAGVs is the low delivery cost of any loading. Korus (2018) estimates the cost per mile could drop from $1.60 via human deliverers to $0.06 with sAGVs. The reasons are twofold, one is the battery, which is smaller as in electric road vehicles. This results in lower acquisitions costs and lowers energy consumption as sAGVs drive much slower than electric road vehicles. The second reason is the labour costs as one operator can oversee roughly 100 robots at the same time (Korus, 2018). Joerss et al. (2016) reported sAGVs to be competing with bike couriers for instant delivery as a premium service. They forecast a relevant increase of the product range beyond food delivery and an increase in the speed of the vehicles as critical for the success of sAGVs in the future last-mile.

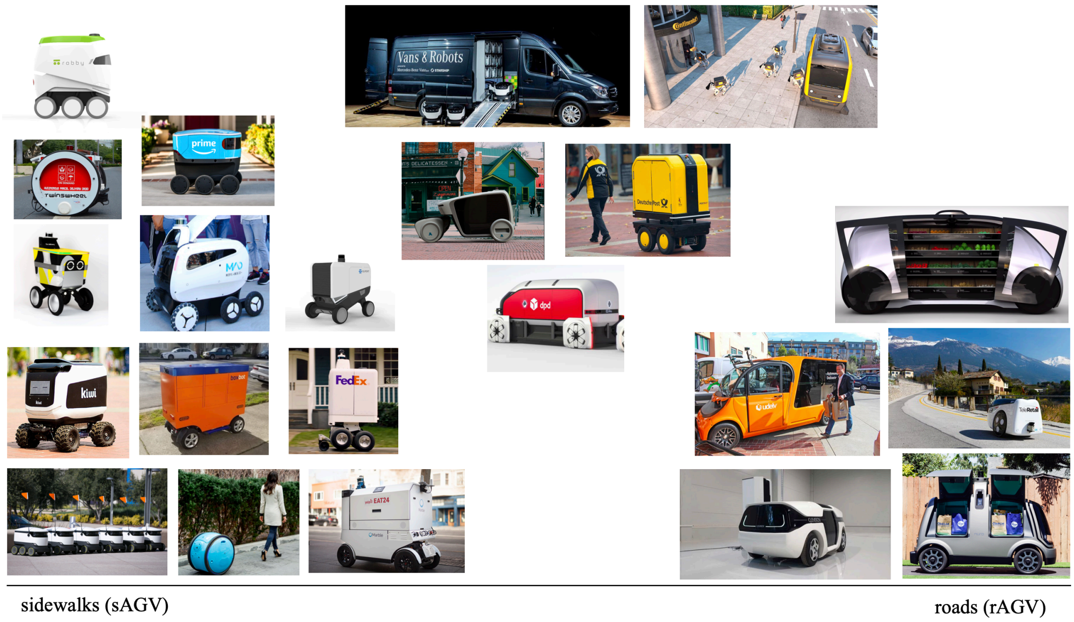


Figure 7: *AGVs for delivery classification*

(own representation based on desk research)

Table 2 below serves an overview of the leading players in the market, founded during the last five years. *Starships technologies* as the publicly known first company with the focus on sAGVs received the highest funding of US$42.2 million to roll out their service globally (Starships Technologies, 2019).

The main competitors listed below do only provide a general overview of the market dynamics and do not reflect the entire market. The several industry partnerships of the main competitors with CEP-companies (Table 2), as well as the recent acquisition of *Dispatch* from *Amazon*

(Harris, 2019) shows a rapidly changing market for AGVs and the recognized value for parcel delivery. Boysen, Schwerdfeger, et al. (2018) even present a truck-based sAGV delivery, which means, a truck loads sAGVs, drives to a drop-off point where the sAGVs start the delivery from the truck to the consumer. A similar approach was the delivery dog concept of *Continental*, carrying packages and climbing stairs and recently attracted considerable attention (Vincent, 2019). Other examples are shown which use AGVs for different applications and might be potential new entrants for urban last-mile delivery, as the technological know-how is disposable.

Company	Founded in	Pilot test/ Publication	Operational characteristics	Funding (in USD)	Country	Industry collaboration/ partnerships	Focus activities
Main competitors							
Starships Technologies	2014	2015	Sidewalk	42.2M	US & Estonia	Mercedes Benz; Dominos; Jus	
Marble	2015		Sidewalk	15M	US	Yelp	
Dispatch (now Amazon Scout)	2015		Sidewalk	2M	US	Amazon	
Robby Technologies	2016		Sidewalk	5.5M	US	PepsiCo	
Boxbot	2016		Sidewalk	9M	US	-	
KiwiBot	2017		Sidewalk	2M	US & Colombia	-	
Eliport	2017		Sidewalk	Seed	Spain	-	
Postmates Serve		2018	Sidewalk	678M	US	Ford	
Twinswheel	2016	2019	Sidewalk	-	France	La poste	
Effidence/DPDHL Postbot		2017	Sidewalk	-	France & Germany	DPDHL	
Meituan		2018	Sidewalk	-	China	GM, Nvidia	Autonomous ground delivery in last mile for food, groceries and post and parcel, mainly operating on sidewalks
Arti robots	2018		Sidewalk	-	Austria	DPDHL, Austrian Post	
Helloworldrobotics	2018		Sidewalk	-	China	-	
Piaggio Gita		2015	Sidewalk	-	Italy	-	
FedEx Samy Day Bot		2019	Sidewalk	-	US	FedEx	
Alibaba Cainiao Gplus		2018	Sidewalk & Road	-	China	Alibaba	
Bedestrian	2017		Sidewalk & Road	-	US	-	
Anybotics and Continental		2019	Sidewalk & Road	-	Switzerland & Germany	Continental	
Aitonomi Teleretail	2014		Road	1.1M	Switzerland	Swiss Post	
Ducktrain	2018		Road	-	Germany	-	
Other categorical examples							
Nuro	2016		Road	1B	US	-	
Udelv	2017		Road	-	US	Walmart	
Cleveron		2018	Road	-	Estonia	-	
Spring Mobility	2017		Road	-	Germany	-	
Next Future Transportation	2015		Road	5 M	US	-	
Navya	2014		Road	64.1M	France	-	Autnomous ground vehicles within diverse applications from hospitality over personal transportation to grocery delivery or warehousing
Local Motors Olli	2007		Road	250K	US	-	
Robomart	2017		Road	-	US	-	
Waymo	2009		Road	-	US	-	
Aethon	2001		Indoor	-	US	-	
Savioke Relay	2013		Indoor	35M	US	-	
Scallog	2013		Indoor	-	France	-	
Segways Loomo		2019	Indoor	-	US	-	

Table 2: *Overview of the main market players in AGV's for delivery*

(own representation based on desk research)

Independent from the operational location and the application area, AGVs use multiple technologies to move around safely. The technologies need to answer three distinctive questions for the vehicle: where the vehicle is, what is happening around, and how to get to the final destination (Zhao, Liang, & Chen, 2018). The interconnected hardware and software components are highly complex and change continuously through new developments. The main hardware components are different sensors (visual, laser and radar) as well as mapping technologies (GPS) but only the connectivity and data processing through machine learning makes self-driving vehicles possible (See Appendix G)

2.4 Technology Acceptance Model and Technology Readiness Index

In this section, the theoretical models used in the methodological part are introduced in their originality. Subsequently, the adoption of the models to the underlying technology and service innovation will be presented in the methodological part of this dissertation.

2.4.1 Technology Acceptance Model

The Technology Adoption Model (TAM) is a widely used model for user acceptance and usage of technology in different areas. Firstly introduced by Davis (1986) and developed from the Theory of Reasoned Action (TRA) by Ajzen & Fishbein (1980), to predict and explain the reasons for the acceptance or non-acceptance by users. It comprises external variables and aims to discover their impact on internal beliefs, attitudes, and intentions (Davis, Bagozzi, & Warshaw, 1989). In specific, the TAM measures the causal relationships between perceived usefulness **(PU)**, perceived ease of use **(PEOU)** and the user's attitudes, intention and actual adoption of technology (Davis et al., 1989). **(PU)** in an organizational context represents the subjective probability of increasing his or her job performance with the use of a specific application system (Davis et al., 1989). **(PEOU)** serves the degree to which the prospective user assumes the system to be free of effort (Davis et al., 1989). **(PEOU)** directly affects a person's attitude **(A)** and **(PU)**. The **(PU)** has a direct influence on both, the behavioral intention to use **(BI)** and a person's attitude **(A)**. The relationships and different components are displayed in Figure 8 below. Robot acceptance tested with the TAM is a growing and diverse direction in literature, in the field of Human-Robot Interaction (HRI).

For example Van Eeuwen (2017) observes the acceptance of chatbots among millennials; Heerink, Kröse, Evers, & Wielinga (2009) suggest an adapted TAM to test the user's acceptance of assistive social robots for elderly care environments; Ezer, Fisk, & Rogers (2009) looked into the variable age as a differentiator for the acceptance of domestic robots; De Graaf & Ben Allouch (2013) explore a variety of potential influencing variables for the acceptance of social robots; and Bröhl, Nelles, Brandl, & Mertens (2016) build a model to test the acceptance in a production setting for industrial robots. Correspondingly the technological acceptance of autonomous vehicles is tested but focuses on personal transportation. The studies reveal users generally being positive about autonomous vehicles. But, skepticism, missing trust in the technology, uncertainty about safety and the loss of control are present in the society, as Fradrich & Lenz (2016), Nordhoff, de Winter, Kyriakidis, van Arem, & Happee (2018) and (Choi & Ji, 2015) reported among others.

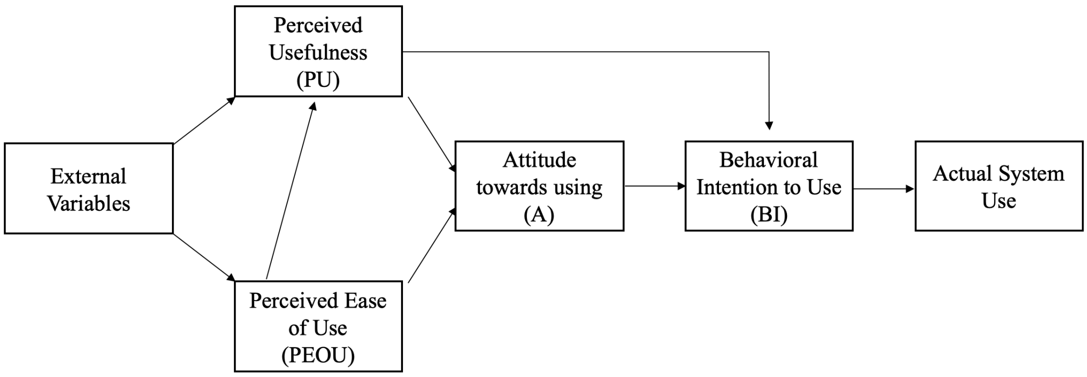


Figure 8: *Technology Acceptance Model*

(Davis et al., 1989)

2.4.2 Technology Readiness Index

The Technology Readiness Index (TRI) allows determining a person's general inclination to use new technologies (Parasuraman, 2000). Technologies tend to get more sophisticated and the degree for interacting with machines for products and services likewise. The readiness of people to interact and use technologies like self-service machines is still at an early stage in research (Parasuraman, 2000). This model includes four dimensions, of which Optimism **(OPT)** and Innovativeness **(INN)** act as motivators and Discomfort **(DIS)** and Insecurity **(INS)** as inhibitors for technology readiness. Optimism characterizes the positive view of technology, the user's perception of increased control, flexibility, and efficiency through technology. Innovativeness relates to a tendency to perceive himself as a technology pioneer and thought leader (Parasuraman, 2000). Discomfort stands for lack of control and a feeling of being overwhelmed by technology. Insecurity expresses distrust and skepticism about its ability to work properly (Parasuraman, 2000). These dimensions were empirically tested with a predefined subset of items and the correlation between people's TRI, and their tendency to employ technology was confirmed by Parasuraman (2000) and refined by the TRI 2.0 (Parasuraman & Colby, 2015). In between, not only several researchers have used TRI 1.0 and proved the concept in several contexts, but also today's core technologies enabling e-commerce, smartphones, and robotics were developed.

3. METHODOLOGY

3.1 Research Approach

The novelty of sAGVs in the delivery setting culminates in a dynamic and competitive environment for businesses as well as unexperienced terrain for consumers, such that it would be misleading to predict the adoptability of the technology by both, industry and consumers. Therefore, the goal in this exploratory study is to examine the current challenges and potential impact of sAGVs in the last-mile delivery from different viewpoints, without providing conclusive evidence. The research follows a multi-method evaluation design with the two main rationales of **(1) expansion** and **(2) triangulation.**

(1) **"**Seeks to extend the breadth and range of inquiry by analyzing them from different perspectives." (Greene, Caracelli, & Graham, 1989, p.259)

(2) "Seeks convergence, corroboration, correspondence of results from the different methods." (Greene, Caracelli, & Graham, 1989, p.259)

Data was collected cross-sectional and simultaneously with the use of different instruments (Bryman, 2006). However, as Bryman (2006) stated, other rationales could be ascribed to the design as well. Especially, **(3) complementarity** in elaborating parts of the qualitative data with the quantitative data afterwards (Greene et al., 1989). The research design is presented below in Figure 9 and will be explained in more detail in the following.

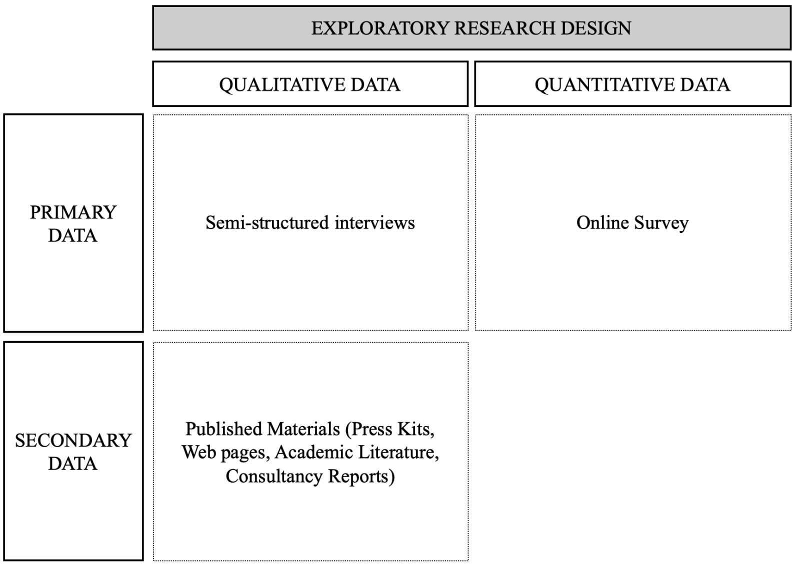


Figure 9: *Visual representation of the research design*

(own representation)

3.2 Secondary Data

The secondary data was collected at first to provide a general understanding of the managerial theory, the CEP-industry's challenges and opportunities, as well as technological classifications for the further course of the work in chapter two. However, desk research on the competitor landscape and technology of AGVs serves as the starting point for the collection of primary data and complements the results throughout. The data sources vary from academic literature, newspaper articles to consultancy reports and web pages.

3.3 Primary Data

The collection of primary data was divided into two steps to achieve a comprehensive overview of the different stakeholders in the field of AGVs for delivery, as well as to increase the research quality by validating one part of the results of the in-depth interviews with the online survey. In-depth interviews with professionals in the field of AGVs as a method was chosen to nourish the first findings in order to answer RQ3 and RQ4. To complement the industry's qualitative results, a quantitative consumer survey was conducted to enrich the findings with a further critical stakeholder opinion and answer RQ5 and RQ6.

3.3.1 In-depth interviews

In total, 28 potential participants were approached of which 5 agreed on a personal telephone interview of around 25 minutes, and one offered a pre-written Q&A for press purposes with relevant information. They were based on a questionnaire – detailed in Appendix H – represented in ten questions and divided in three parts with the aim to complement the desk research findings. The first part consisted of a short introduction of the company, the personal role, as well as the company's activities in the last-mile and respective challenges. The second part touched on the current and future strategic direction. The third part was about the technological maturity and the consumer's perception of AGVs. The open-ended questions and semi-structural approach allowed for insights outside of the pre-defined questions (Wengraf, 2001).

The sample of eligible interview candidates was chosen based on the knowledge about AGVs in last-mile delivery, including sidewalk and road AGVs. Three different stakeholder groups were approached to guarantee diverse perspectives. Representatives of CEP-companies as the incumbents, the technology providers as the new entrants, as well as consultancies and financial institutions with relevant industry knowledge. Four interviews were conducted with technology providers and one with an industry expert. Three experts were the CEO's themselves, one a Relationship Director and one a Marketing & Strategy representative. A comprehensive description can be found in Table 3.

The Interviews were transcribed in detail as a preparation for the data analysis. Afterwards, the data was sorted, reordered and organized by questions (See Appendix I). Findings were drawn after organizing the data by theme and observing similar patterns among different respondents (See Appendix J).

#	Name	Company	Country	Stakeholder group (1) - (3)	Position
1	Konstantin Lassning	ARTI Robotics	Austria	(2) Technology Provider	CEO
2	Damien Declercq	Spring Mobility	Germany	(2) Technology Provider	CEO
3	Torsten Scholl	Teleretail	Switzerland	(2) Technology Provider	CEO
4	PNS*	Delivery Bot Startup**	USA	(2) Technology Provider	Growth, Strategy & Marketing
5	PNS*	Financial Institution**	United Kingdom	(3) Industry Expert	Relationship Director Manufacturing, Transport & Logistics

*prefers not to say
**generalized as particpant wants to stay anonymous

Table 3: *Profiles of the Interviewees*

(own representation)

3.3.2 Online survey

The second data source was an online survey to gather insights from a consumer perspective. As the technology of sAGVs has only recently gained awareness and is yet not commercially in action, the TAM cannot be applied in his originality and has been slightly adopted (Figure 10). Bröhl et al. (2016) included a similar variable to test the user's technology affinity, as well as Nordhoff, de Winter, Kyriakidis, van Arem, & Happee (2018) used comparable measures. Lin, Shih, & Sher (2007) suggest combining the TAM and the TRI to detect differences in technology acceptance among groups. This combination has a good fit to the underlying technological setting as the attitude towards AGVs differs among groups.
The used model will include four items for each dimension, of which three are taken unchanged from the classical TRI by Parasuraman (2000), and one is suited to modern technologies without losing the generalized character of the items.

The TAM measures the user's reactions after the virtual exposure of the underlying technological setting, sAGVs for delivery. The usually tested perceived ease of use **(PEOU)** in the TAM was removed, as sAGVs or related technologies cannot be observed by the public and hence the data sample would see difficulties in estimating the perceived ease of use.
Here, the variable **(A)** captures an individual's positive or negative feelings towards the technology, whereas the variable **(BI)** focuses on the consideration to use the technology in the future. Compared to the TRAM by Lin et al. (2007) mentioned above, **(A)** is perceived as a valuable indicator and was kept in the model, due to the early stage of the technology. All variable items for the TAM, including (**PU)**, (**A)** and (**BI)** were tailored to the underlying technology and will be presented in the results part of this dissertation. Therefore, the following hypotheses are defined and illustrated in Figure 10.

H1. There is a positive relation between perceived usefulness of sAGVs for delivery and the consumer's attitude towards them
H2. There is a positive relation between the consumer's attitude towards sAGVs for delivery and the behavioral intention to use them
H3. There is a positive relation between the perceived usefulness of sAGVs for delivery and the behavioral intention to use them
H4. There is a positive relation between the consumer's technology readiness and the behavioral intention to use sAGVs
H4a. There is a positive relation between the Optimism factor of consumer's technology readiness and the behavioral intention to use sAGVs
H4b. There is a positive relation between the Innovativeness factor of consumer's technology readiness and the behavioral intention to use sAGVs
H4c. There is a negative relation between the Discomfort factor of consumer's technology readiness and the behavioral intention to use sAGVs
H4d. There is a negative relation between the Optimism factor of consumer's technology readiness and the behavioral intention to use sAGVs

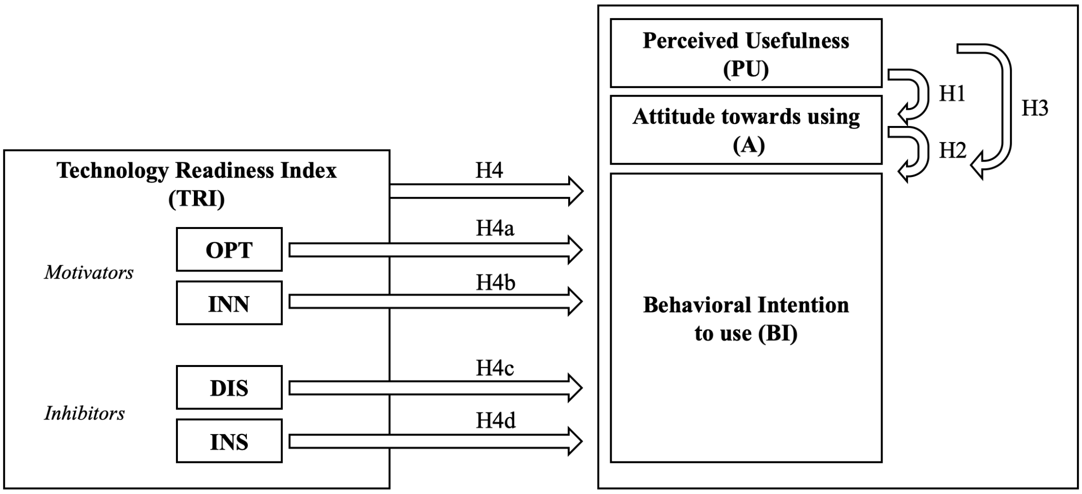


Figure 10: *Summary of proposed hypotheses of the study*

The nature of questions in the online survey about the parcel delivery, allows the target population to be generally broad in characteristics and does not require any prior knowledge. A pilot survey with 10 respondents was first conducted in order to sharpen the understanding of the questionnaire. Afterwards, the distribution of the online survey was executed via several online channels and social media.

All answers were collected anonymously, as the personal identity of the persons was not decisive for the analysis. Due to the exploratory nature of the research, the analysis was performed by using descriptive statistics, such as mean, standard deviation and correlation. The survey was structured in four parts. First, generic information about delivery behavior as well as a self-assessment of knowledge about autonomous vehicles were required. Second, the TRI was applied before showing the consumer experience of the new service innovation of parcel delivery with the use of sAGVs as a technology. The third part was designed after the TAM with the presented variables, before concluding with demographical data, such as gender, age, occupation and nationality (See Appendix K).

The measurement scale for the statistical analysis of Likert questions causes controversy among researchers as Murray (2013) compared. It is important to mention how the data is going to be treated as it allows for different statistical analyses, either parametric or non-parametric tests. In this case, the descriptive statistics for the sample description are interpreted as ordinal data and only Likert-type questions, whereas the Likert scales in the model are formed from several items, except perceived usefulness. This, as well as the use of the same phrasing and including numbers in the questions (1 strongly disagree to 7 strongly agree) allows for the interpretation as interval data for the hypotheses testing (Allen & Seaman, 2007; Boone & Boone, 2012).

4. RESULTS AND DISCUSSION

The core of the analysis is to assess the implementation feasibility of AGVs to overcome the challenges in urban last-mile delivery. The qualitative data provides the current market developments and implementation barriers of AGVs, whereas, the quantitative data analysis, exposes the consumer's acceptance of sAGVs.

4.1 Results from qualitative data collection

4.1.1 The market environment and advantages of AGVs

As introduced at the end of chapter two, the interviewees also agree that AGVs can be classified according to their (1) main operational location, either sidewalk or road and to (2) the degree of autonomy. Several innovative last-mile concepts using AGVs have recently been developed and differ in dimensions like size, speed or design. Not only a dominant design of the future AGV, but also consensus about the operational location and their respective impact on the future last-mile, is missing. The strategic direction of the new entrants is not yet clearly defined. They consider each possible application area in the last-mile as long as the technology can be applied. The interviewees confirmed close collaborations with different partners and the development of prototype AGVs customized for specific use cases. But the long-term goal is to have a modular approach which is adaptable on different last-mile settings, such as parcel lockers, sweepers, garbage collectors and any other transportation tasks. At present, the transportation of small goods, including packages, food or groceries are chosen for feasibility purposes in technology and regulation. These sAGVs are seen as a proof of concept for rAGVs rather than the solution for the CEP-industry's last-mile challenges as one interviewee described it:

"*Not sure about sidewalks as a meaningful future alternative because of pedestrians, we think more of roads as the desired option which will result in a later deployment because of stronger regulation."* (Interviewee 3)

In the beginning, accompanied delivery is the go-to strategy, where sAGVs will carry the load for the deliverer and decrease the physical effort. But the more economically attractive solution for the industry is the independent delivery with a combination of both sAGVs and rAGVs. This opinion is shared among all interviewees and is aptly summarized by one of them:

"*The impact increases with the level of autonomy, right now mapping of zones is time-intensive and costly. New services are not the focus, as the logistics industry wants to use new technologies to save money with the existing processes, meaning to replace the main cost factor human and time in the home delivery*." (Interviewee 1)

These new services include guaranteed deliveries for specific time periods (also night and weekend), which could be purchased for an extra fee. Also, sAGVs add a new level of flexibility at a cheap and environmentally friendly price. The flexibility and low price create new business opportunities with delivery for physical retail stores, pharmacies, cleaning services, just to mention few. The contemporary business models of new entrants face high corporate risk, as they need to provide and operate the sAGV fleet themselves. The current revenue model is pay per delivery from consumer to technology provider and resembles a courier service at a cheaper rate. Starships technologies, as one example, reports the delivery fees between 1 and 3$ and currently at 1.99$ (Starships Technologies, 2019).
For the future, different solutions are possible such as licensing the technology, acquiring the robot fleet or even selling the full service to the technology provider. The market is too nascent to see a strategic direction of the potential revenue streams of the companies. However, as shown in Table 2, new entrants work closely together with the incumbents of the CEP-industry.

4.1.2 The main implementation barriers of AGVs

The interviewees mentioned in total four implementation barriers which inhibit the commercialization of AGVs.

Regulation:

The missing legal framework for AGVs was the most mentioned barrier from all interviewees. Depending on the geographical region, the regulation for the public use of AGVs is different and sometimes even not existent. On the one hand, a common European regulation is missing and Germany as one example has strict sidewalk regulations with national state supervision. In the US on the other hand, each municipality can decide about their sidewalk utilization. This results in a more open territory for robotic companies with the opportunity for starship technologies to be present in eight US states already. In terms of commercialization the compliance with changing and diverse authorities is the major roadblock and results in a much broader application in closed environments, such as university campuses. One Interviewee sees the main issue for regulators in the responsibilities if something happens:

"*The key risk is regulation as of if an autonomous vehicle is involved in an accident or sort of, who is reliable for that, what does that do with a company's value, brand and so on. A change in regulation clarifies that and de-risks the market*." (Interviewee 5)

Technological maturity & scalability:

All interviewees agreed, that the technology of sAGVs is mature for closed environments or pre-mapped areas although the vehicles still need to be remotely monitored in close proximity. The bots are driving fully autonomously in pre-mapped areas after some human controlled test runs. Then, the human operator only has to intervene if the robot faces any challenges in unexpected situations. To avoid this, the built-in technological components need to be state-of-the-art. The components themselves have been around for a long time but only the joint connectivity allows the robot to maneuver safely through his environments (See Appendix F). One interviewee mentioned data fusion, which enables to merge different types of data (e.g. traffic data and visual data) and the increase in computational power as one key achievement. However, the sensor suite of the robots, including radar, vision and especially laser sensors are the tipping point for a safe navigation. Also, these sensors are by far the most expensive parts of AGVs and also subject to economic scalability. Considering laser sensors, LiDAR is seen as the technology which makes the difference but has a wide price range. Although the interviewees omitted the price topic, Zhao, Liang, & Chen (2018) mentions a price of $80.000 for a laser radar used by Google's self-driving car. Furthermore, certifications for these sensors play a big role in terms of responsibilities and risk assessment for the companies. The higher the price, the higher the quality of the sensors, measured in accuracy and reliability, the higher the possible speed of the vehicles. The interviewees mentioned decreasing prices for sensors and are consequently optimistic towards economical scalability in the future:

"*The scalability will arrive quite soon - economies of scale will kick in with a production volume of hundreds already, as the companies right now just operate with very few prototypes*". (Interviewee 2)

In addition, the profitability of an AGV needs to be seen in the economic context, as long as the AGV undercuts the traditional method in price, a deployment is also reasonable.

"*No matter how expensive the robot is, the economic setting is critical in terms of labor costs*". (Interviewee 1)

Infrastructure:

The biggest infrastructural challenge concerns the last meters of the AGV from sidewalk to doorstep. Some technology providers work on sAGVs which can climb stairs and some of them are already able to overcome obstacles like road edges. One Interviewee mentioned a collaboration with elevator companies to connect the vehicles with the elevator to achieve the same consumer convenience as the deliverer can serve. Also, the route itself, how the sidewalks are utilized, either constructing an additional lane, using the bicycle lanes or just driving naturally among pedestrians, needs clarification. Lastly, in the CEP-industry, the real estate for collection centers, where packages are stored before even entering the last-mile with robotic delivery is expensive and highly demanded. The choice of valid areas for deploying this type of delivery is important and is expected to be suburban areas as one interviewee summarized it aptly with mentioning a not suitable urban area:

"*Somewhere like in London, a last-mile delivery may actually drive 7km a day, but walk 10 km and does the majority up and down the stairs*" (Interviewee 5)

Consumer acceptability:

Although there are several regional differences between consumers when it comes to expectations of technology and the fear of human replacement through robots, the interviewees see the perception of sAGVs of consumers positively. Either consumers do not pay attention at all which is the case for 70%, or, if consumers perceive sAGVs, they have a positive attitude towards them (Starships Technologies, 2019)

"They interact with them a lot and really like them - We have a huge appeal from the community, they start taking pictures, even the kids." (Interviewee 4)

Not only the perception is seen as positive by the interviewees, but also the consumer's usability of sAGVs does not raise any concerns. It will be integrated in the daily life if consumers will find it helpful and see a value.

"Awareness work from a commercial/marketing perspective needs to be done but as consumers will see the vehicles around anywhere, they will adapt quickly." (Interviewee 2)

4.2 Results from quantitative data collection

In this section, the results from the online survey are presented. First a sample description will be provided with general frequencies and descriptive statistics. Afterwards, the questionnaire is tested for reliability and validity and will be used to test the hypotheses about the consumer's acceptance of sAGVs.

4.2.1 Sample description

Demographics

In total, the survey was accessed by 178 respondents during the data collection phase, of which 30 had missing data and were not used for further analysis. Leaving a total sample of 148 valid answers of which 62.8 % were male and 35.8% female. The majority of the respondents are in the core millennial age group with 85.5% aged between 18 and 34. Regarding the country of origin, even if a total of 26 nationalities were recorded, over half of them were Germans (58.8%) as presented in Table 4 below. Others represents participants from countries only recorded once.

Variable		Frequency	Percent
Age	18-24	46	31.1
	25-34	81	54.7
	35-50	16	10.8
	> 50	5	3.4
Gender	male	93	62.8
	female	53	35.8
	prefers not to say	2	1.4
Occupation	employed	60	40.5
	student	83	56.1
	other	5	3.4
Country of Origin	Germany	87	58.8
	Portugal	12	8.1
	Italy	6	4.1
	Netherlands	5	3.4
	UK	5	3.4
	Denmark	4	2.7
	Austria	3	2.0
	France	3	2.0
	Russian Federation	3	2.0
	Finland	2	1.4
	Spain	2	1.4
	USA	2	1.4
	Others	14	9.3

Table 4: *Demographics of the sample (N=148)*

Delivery Behaviour

Table 5 below shows the delivery behavior of the sample with the descriptive statistics. The mean of 3.32 shows the average deliveries per month, which the participants had to rank on a ratio scale according to their personal priority, including all deliveries possible (e.g. food, apparel, electronics). The median and mode, both serving additional central tendency data for the data sample, show 3 deliveries per month and underline this result. Moreover, the favorite delivery destination of the sample is home, which was chosen by 75% of the sample as priority one, followed by work as the second most favorite priority (See Appendix L). The parcel locker and the pickup shop of the CEP-company were almost equally prioritized, whereas the delivery to a physical store of the retailer was the least favorite.

	Frequency of monthly deliveries	*Delivered to...*				
		home	*work*	*parcel locker*	*pickup shop*	*physical store*
Mean	3.32	1.34	2.87	3.49	3.35	3.95
Median	3.00	1.00	2.00	4.00	3.00	4.00
Mode	3	1	2	3	4	5
Std. Deviation	2.359	0.676	1.372	1.187	1.042	1.078

Table 5: *Descriptive statistics for delivery behaviour*

Perception and self-assessed knowledge about autonomous vehicles

92.6% of the sample already heard about autonomous vehicles and self-assessed their knowledge on a scale from poor to excellent. The remainder had the opportunity to read a summary what autonomous vehicles are and did not rate their knowledge accordingly. The majority with 63.5% of the sample self-assessed their knowledge either good or fair (Table 6).

		Frequency	Percent	Valid Percent	Cumulative Percent
Knowledge about autonomous vehicles	excellent	20	13.5	13.5	13.5
	good	46	31.1	31.1	44.6
	fair	48	32.4	32.4	77.0
	poor	23	15.6	15.6	92.6
	no knowledge	11	7.4	7.4	100.0

Table 6: *Frequency statistics for self-assessed knowledge about autonomous vehicles*

Consumer's acceptability of sAGVs for delivery

In order to validate the interview results for consumer's acceptability, the survey participants were asked to reveal their feelings towards the presented concept of sAGVs in delivery and the corresponding consumer experience. Figure 11 shows a strong agreement for positive feelings with *"curious"* as the emotion most agreed on with 87.1 % showing agreement, followed by *"happy"* with 83.1%. The sentiment of the remaining emotions is rather negative than positive and results in a disagreement among the participants, which can be observed by the median value, being either 3 or below for *"scared"*, *"alarmed"* and *"angry"*. Remarkable is the clear result for *"angry"* with a percentage of 39.9% of all respondents for "strongly disagree".

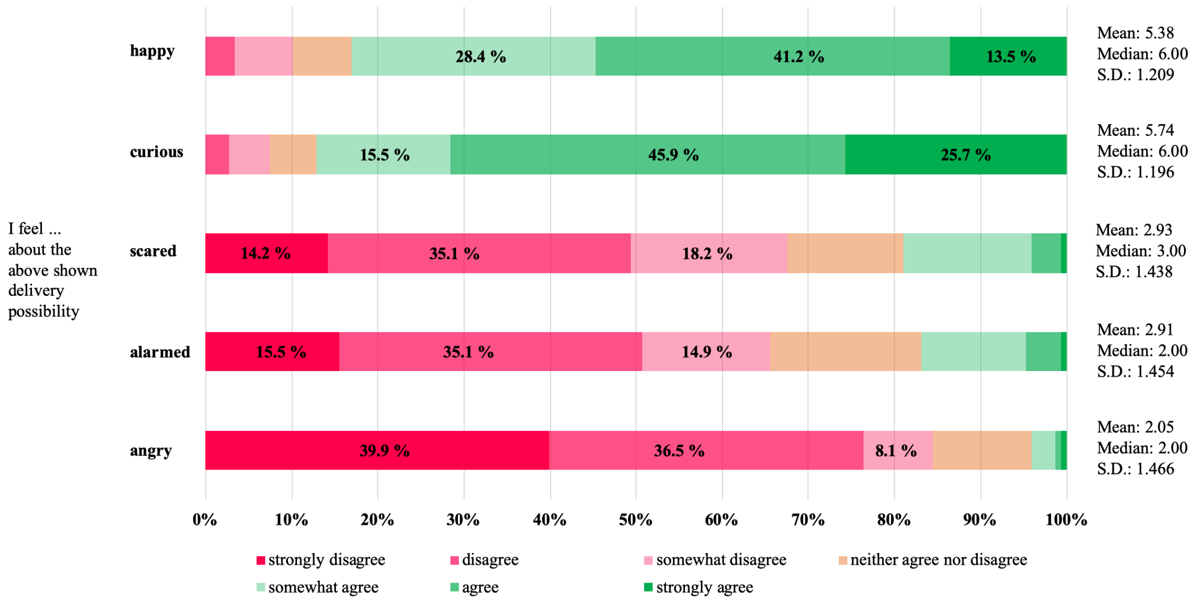


Figure 11: *Consumer's feelings about sidewalk AGVs for delivery*

Based on the literature review, the main benefits and shortcomings accompanying delivery with autonomous vehicles were questioned in terms of motivation to use or not use sAGVs as a future delivery method. Table 7 shows, that *"lower delivery costs"* for the consumer has the highest mean, followed by increasing *"convenience and flexibility"*, as well as a more *"positive impact on the environment"* than traditional methods. The median of 6 throughout indicates the samples central tendency to "agree" on the usage for those reasons.

The variable *"human-robot-interaction"* represents the consumer's willingness to use sAGVs because they like to interact with a robot. This is the most controversial variable among the sample with a mean of 3.63 (Median= 4.00, Mode=2). Also, the standard deviation is the highest among the benefits with 1.683 and implies the average distance from the mean. As a score of 4 is the neutral point, the data sample is indecisive in this criterion. The percentages of frequencies for the higher end (somewhat agree, agree and strongly agree) indicates *"convenience and flexibility"* as the benefit most of the data sample agreed on and *"human-robot-interaction"* as the least.

For the shortcomings of sAGVs, the sample most often observed answer was "somewhat disagree", which can be seen by the mode of 2. As the median for *"safety & security"* differs from the other two reasons with 4 instead of 3, as well as the mean is higher, it can be concluded that *"safety & security"* is of the strongest concern of these shortcomings for the data sample. The variable "*human-worker replacement"* captures the worries of the consumer about the human deliverer getting replaced by sAGVs. Here, the distribution in the histograms is the most left-sided and suggest the least concern of the data sample (See Appendix M). Accordingly, the cumulative percentages of frequencies for the lower end of the scale (somewhat disagree, disagree and strongly disagree) is the highest for "*human-worker replacement" with* 62.8%, followed by *"annoyance on sidewalks"* (51.4%) and *"safety and security"* (44.6%).

Asked about the *"overall usefulness"*, the sample reacted positively, with 84.5% showing agreement, of which 24.3% chose "slightly useful", 45.3% "moderately useful", and 14.9% "extremely useful".

		I would consider to use sidewalk AGVs because…				**I would not consider to use sidewalk AGVs because…**		
	Overall usefulness	*Convenience & Flexibility*	*Environment*	*Human-Robot Interaction*	*Lower Delivery Costs*	*Human Worker Replacement*	*Annoyance on sidewalks*	*Safety & Security*
Descriptive Statistics								
Mean	5.39	5.39	5.27	3.63	5.55	3.14	3.53	3.85
Median	6	6.00	6.00	4.00	6.00	3.00	3.00	4.00
Mode	6	6	6	2	6	2	2	2
Std. Deviation	1.388	1.353	1.417	1.683	1.347	1.615	1.643	1.751
Frequencies in %								
Disagreement (1, 2 & 3)	11.5%	10.1%	10.8%	45.3%	8.1%	62.8%	51.4%	44.6%
Neither…nor (4)	4.0%	7.4%	15.6%	21.5%	12.8%	15.6%	16.2%	14.8%
Agreement (5, 6 & 7)	84.5%	82.5%	73.6%	33.2%	79.1%	21.6%	32.4%	40.6%

Table 7: *Descriptive and frequency statistics on perceived usefulness of sAGVs*

In addition, the participants were asked about their observed major concerns and benefits with the help of an open text entry field. In total, 68 text entries were recorded and analyzed, of which 53 had at least one clearly identified concern or benefit listed (See Appendix N). In general, the statements were phrased positively, but mentioned some concerns (Table 8).

The major concern is the safety of their ordered item and the potential danger of a destroyed robot. The second major concern combines different proof of concept remarks, such as the infrastructure or if it really works as described. The third major concern is that the sidewalk might be overcrowded and is not the best suited location for autonomous delivery robots.
Six concerns were raised about the interaction at home, especially if there is still the need to be at home. The robot specifications mainly encompass concerns about the insufficient size and volume of the robot for parcel delivery. On the one hand three participants are worried about the robot replacing the human deliverer, on the other hand four participants perceive it is a benefit that repetitive tasks and bad working conditions for human deliverers could be replaced through autonomous robots.
Surprisingly costs are not mentioned by any participants in the open text entry although it was the highest scoring benefit above. Convenience in terms of speed, reliability and flexibility is the major benefit with 11 entries.

Major concerns identified	Count*	Major benefits identified	Count*
(1) **Safety** (steal package, destroy the robot)	19	(1) **Convenience** Speed Reliability Flexibility	11
(2) **Proof of concept** (legal, infrastructural, operational)	11		
(3) **Interaction with consumers** (need to be home)	6		
(4) **Robot specifications**	5	(2) **Environment**	3
(5) **Sidewalk**	10	(3) **Jobs**	4
(6) **Environment**	3	(4) **Fun**	1
(7) **Jobs**	3		
Summary	57**		19**

*subjective classification
** simple sum not unique statement counts

Table 8: *Summary of open text entry analysis*

4.2.2 Hypothesis testing

Technology Acceptance Model

(BI) Behavioural intent is the dependent variable in this research model and combines the different items tested about the consumer's consideration to use sAGVs (See Appendix O & Appendix P). A Principal Component Analysis was applied including all 7 items, of which the three no-usage items were reverse coded. A Kaiser-Meyer-Olkin (KMO) value of .789 indicates the data to be suitable for the principal component analysis. The factor loadings show the two different components, including the usage items (BI 1-4) and the no-usage items (BI 5-7). The pattern matrix shows the item “I would not use it because the robot replaces the human worker” closely to both components (Appendix O). All items were combined with the mean, leaving BI as a slightly right skewed but normally distributed variable (See Appendix P).

The mean score of 4.76 (N=148, Median=4.857, SD=.9486) as well as the shift to the right shows the data samples general positive intention to use sAGVs. The independent t-test for differences among gender (t=.941, df=129, p=.3491) was insignificant to the 5% level. ANOVA analyses for age as well as occupation showed both no significant differences among the respective groups (F_{age}=1.730, df_{age}=3, p_{age}=.164); $F_{occupation}$=2.310, $df_{occupation}$=2, $p_{occupation}$=.103). One possible explanation is the age distribution of the data sample with a high share of millennials. Also, the questioned knowledge about autonomous vehicles showed no significant result ($F_{AVKnowledge}$=1.726, $df_{AVKnowledge}$=4, $p_{AVKnowledge}$=.148).

(A) For attitude the same procedure as above for BI was conducted. Two positive feelings and three negative feelings, which were recoded, represent the attitude towards sAGVs of the consumers (Appendix P). The mean score of 5.45 (N=148, Median=5.6, SD=.9735) shows an even stronger right shift of the data sample, indicating a positive attitude towards sAGVs.

(PU) Perceived usefulness was measured with the one item question if consumers perceive sAGVs as useful, rated on a 7-point Likert scale.

Technology Readiness Index

The KMO value of .745 again showed a relevance of a principal component analysis, which showed the predefined four components of the TRI in the rotated factor loadings. However, the reliability analysis using Cronbach’s alpha suggested to delete the fourth item for Innovativeness and Discomfort to surpass the value of .7 which is considered as a critical value to continue the analyses and indicates an acceptable item reliability. Table 9 below displays not only the means, but also the reliability scores for each variable used in the hypotheses testing in the following.

Variables	# of items	Mean	S.D.	Alpha
PU	1	5.39	1.388	-
A	5	5.45	.9735	.799
BI	7	4.76	.9486	.721
TRI	14	4.46	.6379	.765
OPT	4	5.64	.8662	.749
INN	3	4.97	1.185	.796
DIS	3	4.19	1.011	.701
INS	4	3.03	.9338	.713

Table 9: *Research Variables with Cronbach's alpha and means*

The proposed hypotheses were tested first with a correlation matrix (Appendix R) and consequently with simple regression analyses to see if significant relations can be observed in the underlying data sample. The simple regression results for the hypotheses are shown in Table 10. The correlation matrix shows that all relations of the hypotheses have a p-value below .01, indicating a statistical significance and can be supported. The strongest correlation can be seen between (A) and (BI) with .642 and the lowest between (DIS) and (BI) with -.285.

Hypothesis	Path			Std Beta	t-value	p
H1	PU	→	A	.457	6.204	<0.01
H2	A	→	BI	.642	10.123	<0.01
H3	PU	→	BI	.450	6.086	<0.01
H4	TRI	→	BI	.521	7.380	<0.01
H4a	OPT	→	BI	.438	5.883	<0.01
H4b	INN	→	BI	.354	4.572	<0.01
H4c	DIS	→	BI	-.263	-3.288	<0.01
H4d	INS	→	BI	-.285	-3.591	<0.01

Table 10: *Hypothesis testing: simple regression results*

A multiple regression analysis was performed with a stepwise approach, in order to test the model further. Three models were iterated, and the results are observable in Table 11 below. All variables described in the results section were included as independent variables (Age, Gender, Occupation, AVKnowledge, Delivery Frequency, PU, A, TRI, OPT, INN, DIS, INS) to see the relationship on the dependent variable BI. Model 1, which only uses (A) as an independent variable explains 40.9% of the variance in the data, as seen by the adjusted R^2. When considering (PU) and (TRI) in model 3, the explained variance increases slightly to 47.0% and all variables show a significance level below 5%. The highest coefficient is (A) with .410, indicating an increase of .410 units in (BI) when increasing (A) by 1 unit. The stepwise approach shows which variables have the most impact and are statistically significantly predicting the dependent variable. However, as this dissertation is only exploring the relationships between the variables, the model should be perceived as a prospect for future research and will not be further analyzed (See Appendix S).

Model	Variable	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R^2	R^2 adjusted	Std. error of the estimate
		B	Std. Error	Beta					
1	(Constant)	1.370	.339		4.035	.000	.413	.409	.72378
	A	.620	.061	.643	10.107	.000			
2	(Constant)	.504	.431		1.171	.244	.450	.443	.70292
	A	.500	.071	.518	7.046	.000			
	TRI	.341	.109	.229	3.120	.002			
3	(Constant)	.228	.431		.529	.598	.481	.470	.68532
	A	.410	0.76	.425	5.402	.000			
	TRI	.352	.107	.237	3.301	.001			
	PU	.134	.046	.197	2.914	.004			

Table 11: *Multiple regression results*

4.3 Discussion

The findings from this study suggest that AGVs for delivery can improve the current challenges of the urban last-mile and sidewalk AGVs are perceived as positive of consumers with a high potential for acceptance. The interview findings show that only a full level of autonomy can significantly help to overcome the CEP-industry's challenges and are in line with the findings of Xia & Yang (2017) and Bouton et al. (2017).

Moreover, sAGVs will contribute to the future urban last-mile delivery in two dimensions. First, they will proof the concept of rAGVs for the industry, as they have to comply with less safety requirements due to their lower speed and therefore can be implemented sooner from the technological maturity standpoint, as already indicated by Xia & Yang (2017). Second, they will create new value for the consumer in delivery services. On the one hand new products will be available for instant delivery as the prices are low and on the other hand parcels can be requested on demand from a local hub whenever at home. Thus, the possibility for night and weekend delivery rises, which is highly desired by consumers (Lowe & Rigby, 2014). The price range stated by the interviewees is matching the upper pain threshold of consumers to pay for home delivery instead of alternatives, as found by Joerss et al. (2016)

According to the interview findings, two major roadblocks need to be surpassed for the provider of sAGVs for a commercialization. The description of the missing regulatory framework is in line with (Hoffmann & Prause, 2018). The expensive sensorics on sAGVs does not allow for economic scalability as Lee et al. (2016) outlined it, but is subject to change soon, as reported by the interviewees.

As expected, the quantitative results support all three hypotheses on the acceptance (H1-H3) of sAGVs by the consumers and confirm the interview findings of a positive attitude towards sAGVs. The first feelings of the consumers and associated emotions about sAGVs, measured with the attitude variable, has the highest impact on the usage behavior and is in agreement with previous studies (De Graaf & Ben Allouch, 2013). As sAGVs are still in early development no dominant design has been exposed and further research is needed on the consumer's attitude towards different looking robots.

Contrary to most of previous studies, perceived usefulness has not the highest influence for the overall intention to use. One explanation could be that the variable was only measured with one item, resulting in a one directional result of positive perceived usefulness.
As expected and in agreement with Joerss et al. (2016), cost minimization is the strongest factor for consumers to use alternative delivery methods, which raises the question if a premium service of more convenient, flexible and reliable delivery can be feasible to implement for the CEP-industry. Important to realize is that on the one hand consumers do not care about the human deliverer being replaced by an sAGV, but on the other hand also do not like the human-robot interaction component. One additional indicator, that consumers prefer the service for

other reasons than the interaction with the robot shows the high agreement for safety and security and most raised concerns about the parcel being delivered stolen or damaged.

Nonetheless, as already De Graaf & Ben Allouch (2013) expressed, future research is needed to analyze the effect of the enjoyment of human robot interaction on the acceptance of robots. Trust in the reliable performance of sAGV is a high concern of users and is in parallel with the research about personal transportation AGVs of Fradrich & Lenz (2016) and Nordhoff et al. (2018).

Remarkably, consumers do not reject the operational location of sidewalks clearly because sAGVs would annoy them, rather they are curious about how the implementation will look like in reality and question if the sidewalk has the right capacity to handle plenty deliveries, as also raised by some interviewees.

Surprisingly, the previous knowledge about autonomous vehicles has no major impact on the acceptance of the participants. In like manner Ezer et al. (2009) does not see a significant effect of previous robot experience on the acceptance of domestic robots. Differences in age had no significant effect on the acceptance of sAGVs and back Ezer et al. (2009) findings for domestic robots. Conversely, general technology readiness had a significant effect on the use of sAGVs and Hypotheses H4a-H4d were supported.

5. CONCLUSIONS AND LIMITATIONS

5.1 Main Findings and Conclusion

The aim of this dissertation is to identify the future extent of autonomous vehicles in urban last-mile delivery and the role of consumer's acceptance within this development. The rise of e-commerce forced mainly the CEP-industry into a strategic change in which emerging technologies play a significant role for service innovation. To be able to identify the future potential of one particular solution to be implemented by the industry and accepted by the consumer, it is essential to understand the variables influencing the situation for each stakeholder. To accomplish this, an extensive literature review on current last-mile challenges, the CEP-industry, the technology of AGVs and technology acceptance models has been conducted. This provided a basic understanding of the differences in autonomous vehicles as well as the competitive market environment. Primary qualitative research revealed the current constraints and the future feasibility for the implementation of AGVs.

The potential impact of AGVs for the urban last-mile differs between the operational location, sidewalk or road, and the level of autonomy from semi-autonomous to full-autonomous. Fully autonomous road-AGVs are identified as the highly desired but to-date not feasible solution. In this way, the CEP-industry can exploit the entire cost-savings of the human worker's hourly wage and dynamically route the vehicles efficiently. The challenges of maintaining margins, increasing efficiency, decreasing environmental impact, as well as adapting to changing consumer demands will be positively influenced by fully autonomous rAGVs to a significant level.

However, the future of the urban last-mile landscape is prospected to be a synergy of connected vehicles and diversified service concepts working together with humans rather than one vehicle or technology being adopted as the dominant design.

The most feasible implementation of autonomous vehicles and one part of the future system are sidewalk-AGVs. Even though sAGVs are not the sole response on the last-mile challenges, the implementation can improve the situation for the CEP-industry in two dimensions.

First, act as a **proof of concept** and **door opener for rAGVs**. Sidewalk-AGVs are less costly as they drive slower and on sidewalks and do not need the same technological equipment standard then rAGVs. Still, missing economies of scale for primarily radar sensors slow the commercialization down. Moreover, legislation for the operational location is less strict, as sidewalks are in the responsibility of federal states or even municipalities, rather than the national road traffic regulations. But, as legislation differs in each country and generates implementation barriers, the current deployment is restricted to test areas and closed environments. Another critical variable is minimum wage, as the management decision to replace the human worker due to cost savings requires strong argumentation. Consumers have a positive attitude towards sAGVs and would use them in general, as long as the safety of their ordered item, which is the biggest concern, is ensured. Certainly, lower costs as traditional delivery creates the baseline for consumers' considerations to use sAGVs. The human deliverers potential job loss is not a reason to omit sAGVs for delivery.

Second, **new business opportunities** can be created not only for CEP-companies providing premium services with a guaranteed and flexible delivery also at night and weekends, but also for small retailers, such as cafés, grocery stores or even pharmacies, which failed in offering delivery services due to cost reasons. In practice, sAGV fleets are provided from the robot manufacturer to retailers and consumers can order via smartphone application to specifically choose sAGV delivery. Currently, the focus is on groceries and food delivery for feasibility reasons, but other applications for the technology are of high priority because of more significant market sizes.

The pioneering countries in the implementation of sAGVs require high minimum wage standards, liberal and decentralized laws on sidewalks, a reasonable amount of sub-urban areas with highly developed infrastructure, including constructional and digital, as well as technology ready consumers. It is currently not possible to say which business strategy will prevail, but the trend of incumbents cooperating with the technology provider shows a high interest of the industry developing and implementing own fleets. Since sAGVs rather create new premium services than solving the current last-mile challenge of the CEP-industry, and proactive behavior to overcome the regulatory barrier is needed, consumers need to be patient to experience the benefits of sAGVs.

5.2 Limitations and future research

This dissertation has some limitations which need to be considered when interpreting results, discussion and conclusion. First, the nature of this dissertation is exploratory and the concept of sAGVs is not yet commercialized and consequently does not allow for probability sampling. Both the qualitative and the quantitative part of data collection suffer from self-selection bias of the sample, as the majority of the respondents of the survey belong to the cohort of European millennials, and the interview candidates are limited to technology provider. Although the technology providers deliver a comprehensive overview of the current implementation barriers, an industry standpoint would complement the results in scope. An assessment of the economic feasibility for the industry is questionable, as the reported delivery price reductions are tremendous, but the underlying calculations are not disclosed.

In addition, the sample size in both cases does not allow for external validity as the findings cannot be generalized for other age groups, regions for the consumer's behavior, as well as for the complete market environment of sAGVs.

The changes to the original technology acceptance model and technology readiness index, which were needed for the context of sAGVs, creates a loss in reliability of the items. Another limitation is the focus of the quantitative data collection on parcel delivery as a service, neglecting local delivery of food and groceries. On the same page, the presentation of the sAGVs for delivery concept was not shown in relation to other potential solutions for the last-mile challenges, such that participants could not compare and choose their preferred option.

Furthermore, the results are based on consumers' perceptions of their own behavior, which can deviate from actual behavior and the usage of sAGVs. The description of the consumer experience when using sAGVs as a delivery method shows only the main functionalities and benefits and might not represent the real-life experience. Moreover, perceived ease of use was excluded in the model and is suggested to be tested in future research, ideally the sample would include users of sAGVs, which was not possible for the scope of the thesis, as only few operations are deployed on university campuses mainly in the US. This could be a possible direction for future research, to find the specific services consumers would like to use sAGVs for and if other options would be more preferred. Subsequently the consumers' satisfaction and a comparison between robotic delivery and human delivery can be tested.

Also, other last-mile concepts, like crowdsourced delivery or in-car delivery need to be analyzed in a comparative manner with sAGVs. Besides, this dissertation focuses on urban areas and neglects rural delivery as a potential application of AGVs.

The field of consumers' acceptance of autonomous vehicles is still in its infancy and as the technological maturity will increase, new directions will arise. I hope that this dissertation will help academics and practitioners to get a first introduction to the future potential of AGVs in the urban last-mile for delivery.

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APPENDICES

Appendix A: CEP-market in Germany: Characteristics of the main competitors

CEP Market Germany	Revenue in mn €		Consignment volumes in mn	Employees	Pickup Shops
	2015	2017	2017	2017	2017
Total market	17410 [2]	19400 [2]	3335 [2]	229600 [2]	n/a
Deutsche Post DHL Group (DPDHL)	5900 [4]	9640 [1] 5190 [3] (only parcel divison)	1376 [3]	180479 [3]	11000 (PaketShops) [3] 13000 (Retail Stores) [3] 2500 (Sales Points) [3]
United Parcel Services (UPS)	1550 [4]	1900 [1]	n/a	>20000 [8]	3400 [8]
Hermes Group (part of Otto Group)	1250 [4]	1850 [1]	463,3 [7] (approximation of german revenue share (60,5%) from total volume of 766mn consignments)	5555 [6]	15000 [6]
Dynamic Parcel Distribution (DPD) (part of Geoposte/Le Groupe La Poste)	1600 [4]	1800 [1]	375 [9]	9500 [9]	6500 [9]
General Logistics Services (GLS) (part of royal mail group)	790 [4]	>790mn [5] (1.800: Germany,Italy&France) whereof Germany biggest market)	584 [10] (in Europe)	18000 [10] (in Europe)	5000 [10]

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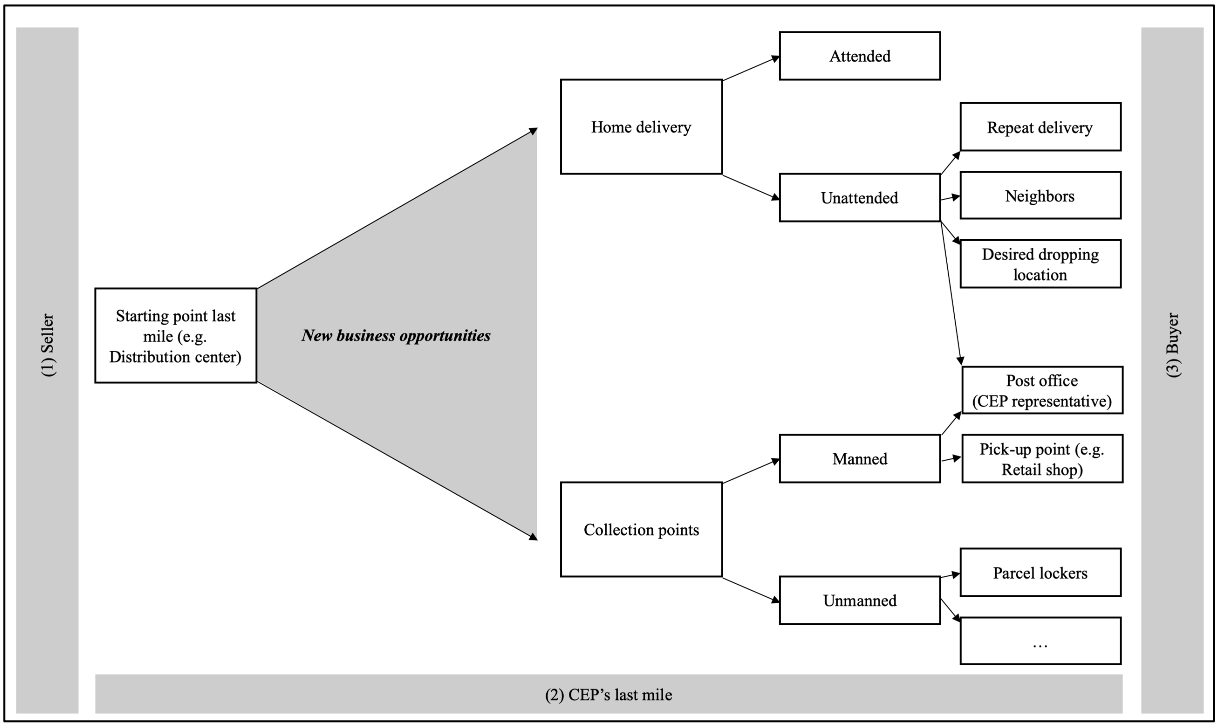
Appendix B: Analysis of DPDHL Annual reports over time

Revenue DPDHL by segment in mn €	2010	2011	2012	2013	2014	2015	2016	2017
Mail	**13,912**	**13,973**	**13972**	**14452**	-	-	-	-
Post, E-Commerce & Parcel	-	-	-	-	**15686**	**16131**	**16797**	**18168**
Express	9,917	11,766	12778	12712	12491	13661	14030	15049
Global Forwarding, Freight	11,243	15,044	15666	14838	14924	14890	13737	14482
Supply Chain	12,183	13,223	14340	14277	14737	15791	13957	14152

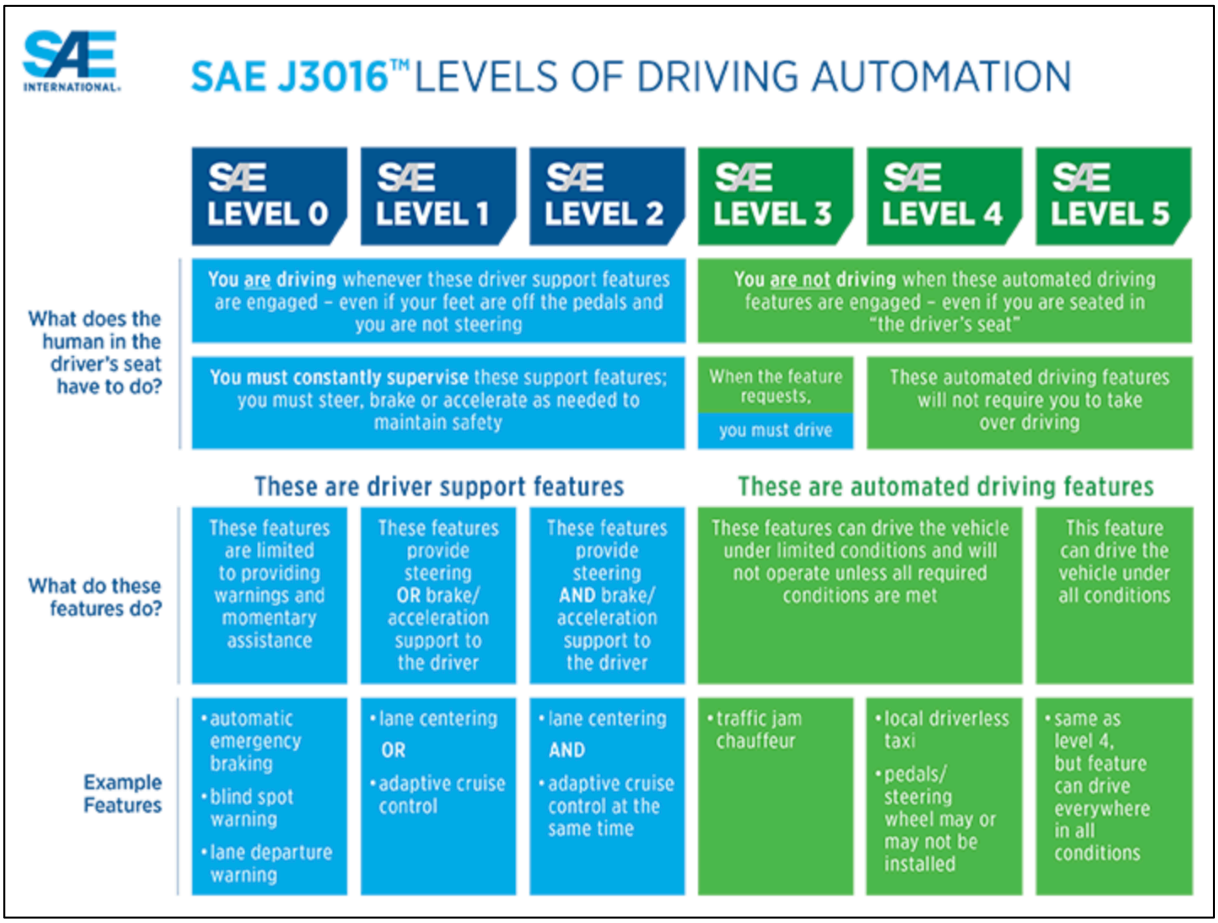
Wordcount DPDHL Annual reports	2010	2011	2012	2013	2014	2015	2016	2017
total page count	*252*	*264*	*230*	*230*	*234*	*224*	*192*	*192*
Parcel	68	122	77	112	150	124	125	113
Mail	**238**	**218**	**172**	**170**	**84**	**63**	**74**	**58**
Post	**881**	**906**	**788**	**747**	**781**	**710**	**545**	**522**
e-Commerce	7	14	6	9	15	19	25	22

Appendix C: Current last-mile delivery options

(own representation based on Gevaers et al.(2011) and Moroz & Polkowski (2016)



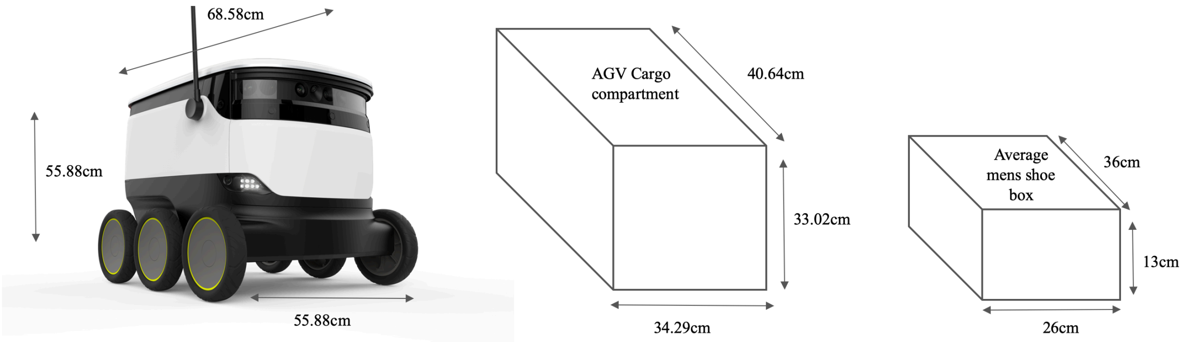
Appendix D: SAE's levels of driving automation (based on (SAE, 2018)*)*



Appendix E: Autonomous parcel lockers concepts

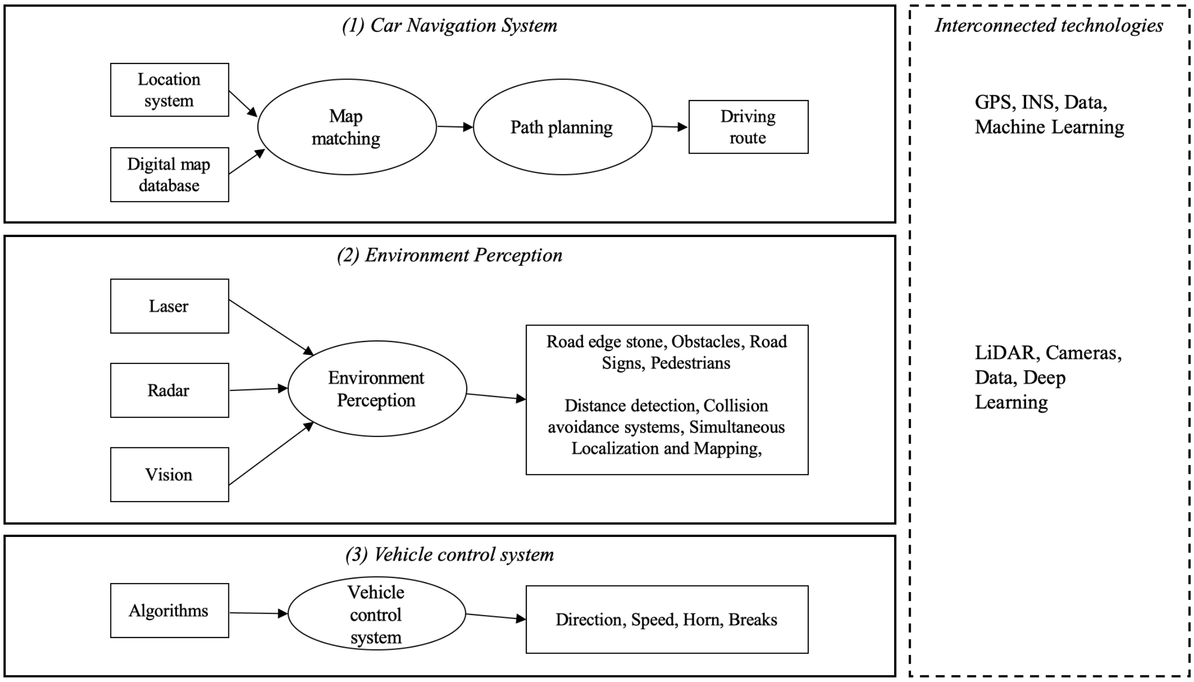
(based on (DPDgroup, 2018; Next Transportation, n.d.)*)*

Appendix F: Technical specifications sidewalk-AGV example of Starships Technologies



Weight Robot: 20kg   Weight Cargo: 10kg   Battery life: ~2h   Max. speed: 6km/h

Appendix G: Unmanned ground vehicles main technical components (own representation based on (Zhao et al., 2018)



Appendix H: Interview questionnaire

Date	Name	Company	Role

Dear Interviewee,

Thank you for your participation, I am conscious your input will positively contribute to my dissertation and the future of autonomous ground delivery.
This research aims to understand what challenges and opportunities are linked to autonomous ground vehicles in delivery, how to overcome them and how is the consumer's willingness to accept this innovation.
This interview is semi-structured in three parts and enables the respondent to flexibly answer outside of the preset questions.

Any doubts? Otherwise we can start with the first question to use your valuable time as efficient as possible.

Part I - Introduction / Company / Industry

Q1	Can you please shortly describe what your **company's objective** is?
Q2	What is your **personal role** within the company?
Q3	What are the **companies activities in terms of last mile delivery**? (special category (food, grocerys, parcel etc.)
Q4	What are the **main challenges** your company is currently facing to achieve the mission/objectives? (external:legal, customer perception; or internal: technological, funding, etc. …)

Part II – Strategic Direction

Q5	What is the **current focus of the business strategy** (building partnerships with food chains, post and parcel companies, selling to the consumer, retail stores etc)
Q6	To what extent are autonomous ground vehicles for delivery **scalable** and what are factors influencing? (Pricing)
Q7	How would you describe the **impact of autonomous ground vehicles** in the e-Commerce-Parcel industry of the future? Which vehicles will be of the most value (droids, vans, parcel lockers)

Part III – Technology & Consumers

Q8	How would you describe the **technological maturity** of autonomous ground delivery vehicles? (ready for take off, long way to go…)
Q9	What have been the **main improvements/technological components** which made the rise of droid startups in delivery so dynamic (LiDar, Computer vision advancements, Hardware, Sensors..)
Q10	What is your experience of the **consumers perceptions** - any barriers to overcome (are they afraid, do they like it)

The last questions is a formal one – how do you want to be represented in the dissertation (anonymously, name, company)

Thank you very much for your valuable time.

Appendix I: Interview transcripts

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Additional Q	
	Can you please shortly describe what your **company's objective** is?	What are the **company's activities in terms of last mile delivery**? (special category (food, groceries, parcel etc.)	What are the **main challenges** your company is currently facing to achieve the mission/objectives? (external:legal, customer perception; or internal: technological, funding, etc. …)	What is the **current focus of the business strategy** (building partnerships with food chains, post and parcel companies, selling to the consumer, retail stores etc)	To what extent are autonomous ground vehicles for delivery **scalable** and what are factors influencing? (Pricing)	How would you describe the **impact of autonomous ground vehicles in the e-Commerce-Parcel industry** of the future? Which vehicles will be of the most value (droids, vans, parcel lockers)	How would you describe the **technological maturity** of autonomous ground delivery vehicles? (ready for take off, long way to go…)	What have been the **main improvements/technological components** which made the rise of droid startups in delivery so dynamic (LiDar, Computer vision advancements, Hardware, Sensors..)	What is your **experience of the consumers perceptions** - any barriers to overcome (are they afraid, do they like it)	What is the **regulatory status** in autonomous ground vehicles, especially on sidewalks?	How will the future look like/the implementation process?
Konstantin Lassning ARTI (CEO)	Young startup building software for autonomous mobile robots, modules to enable autonomy skills in different products (e.g. following of persons, self-driven from point to point) for mainly urban areas	- Focus small and middle loads in urban areas without manipulating the environment (no markers etc.) - Post and Parcel as the main target consumers (DHL challenge, Austrian Post as a customer..) - Focus on CEP because of the existing network but in general developing a product which is adaptable to different usable cases – a general solution to automate transport in urban areas as the technology is pretty similar no matter if parcel delivery or garbage collection but makes the concept more attractive	- One main challenge is the full automation, which means, nowadays a human factor is necessary to load and de-load a robot (where to meet, how long the robot waits), but this period of time is very crucial - Another challenge is the meeting point from a navigation, routing point of view. (E.g. garbage collection: is a time repetitive process with similar location of the bins; parcel: not clearly defined objectives (how many parcels, dependent on human de-loading, different packaging sizes) - automatize a specific zone is time-intensive and not sacalable - Different settings need different technological approaches/subleties: garbage (no human preferences as long as the collection happens), food (time dependent:cold or warm), parcel (safety security of theft for parcels)	- Difficult not really foreseeable - CEP companies are cautious about the dependency, which means if there occurs an issue (not functional anymore) the service would break down - A combined model would be the most suitable where guaranteed services will be purchased (e.g. AGV provider is responsible for the delivery and if the robot has issues the provider needs to take care of delivering no matter what.	- Profitability is an issue as the robot has to undercut a specific price (depends mainly on labor costs) - No matter how expensive the robot is, the economic setting is critical in terms of labor costs	- impact increases with level of autonomy, right now mapping of zones is time-intensive and costly - New services: not the focus as the logistics industry wants to use new technologies to save money with the existing processes (meaning to replace the main cost factor human and time in the home delivery)	- 2017: Pilot project in Graz city center demonstration of autonomous parcel delivery to show how the technology works and if it is functional in the inner city and how the consumers will react. - Positive feedback showed that the technology would be ready in small circumstances with the focus now to unify the cep-industries strategies with the technology readiness - Technological maturity is high but not economic enough today, but we are relaxed and see that the price point will be a result of the developments in the future. We are experiencing always new technologies which differ in the price in the factor of 10	- Sensoric costs: As laser scanners are too expensive and the environment is highly dynamic and unpredictable, companies need to provide a wide suite of different technologies which covers all possible perspectives	- Europe is more conservative and laugh at the technology and critical about the functionality - Fear of human replacement, which is not true in the cep industry as it is a reaction on the too fast market growth - Questions on door opening, steps, etc. but what is the status of the technology and where are the deliverers shortcomings - Expectations are really high on technology (need for a clarification on what can be done and what is not realistic)	- Highly difficult, we already tried to launch a product, but it is a complete grey area in Austria, nobody is able to answer also of the federal authorities. Personal transportation and commercial goods are different settings but both lack in regulation - One opportunity is to be small enough to fall under toy regulations or the accompanying of a robot in proximity - SG has a regulation for punishment if a robot will be disturbed in their mission or delivery	Complexity increases with level of autonomy which is why semi-autonomy is developed to roll out faster and the opportunity is in walking replacement 1: self-driving/transport robot companion (robot drives behind the human deliverer and carries the load) and solves the weight challenge/ capacity Variabilities: self back driving etc. location: 2: station-to-station: intra logistics (universities, companies) 3: station-to-person: robot will be driving to the deliverer to a location
Damien Declercq Spring Mobility (CEO)	Deploying and to some extent operating fleets of self-driving vehicles (utility for cargo applications, self-driving sweeper)	- Focus on the self-driving utility vehicle with the ability to adapt modules on top of it (vending machine, cargo space, or lockers) and currently discussing with parcel companies about the deployability	- Awareness and the maturity of the solutions is not seen as high enough to deploy - Open roads accessibility in Europe because of authorization obstacles	- At the moment jointly deplyong vehicles for a given application but customer decides how the fleet will be operated (by us or themselves) - Market too early to see strategic directions but as soon as the regulatory frameworks arrive this will happen	- The scalability will arrive quite soon - Economies of scale will kick in with a production volume of hundreds already, as the companies right now just operate with very few prototypes - later entrants can skip the prototype phase and start producing with economies of scale (as seen in self-driving shuttle with Olli, Navya, Easy Mile and Baidu)	- The timing is unclear but I see a lot of benefits to implement self-driving fleets	- The technology that is required for getting on open roads at high speed is significantly different from what is required for low-speed application on sidewalks - In closed environments the technology is ready and can be deployed	- The sensors have been around for quite some time and self-driving vehicles in cosed areas have been deployed for more than a decade, now the computational power and the ability to make sense of what the data gathered meant was a limitation in the deployment - Video recognition is one of the enablers - Data fusion: the ability to merge different types of data - the computational power is higher and more affordable - costs of sensors decrease significantly	- pilot of self-driving shuttle showed that consumers dont even recognise that it is self-driving and there is increasing awareness and consciousness - not very afraif about consumers adoption, once it is there it will just be part of daily life - awareness work from a commercial/marketing perspective needs to be done but as consumers will see the vehicles around anywhere they will adapt quickly		

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Additional Q	
	Can you please shortly describe what your **company's objective** is?	What are the **company's activities in terms of last mile delivery**? (special category (food, groceries, parcel etc.)	What are the **main challenges** your company is currently facing to achieve the mission/objectives? (external:legal, customer perception; or internal: technological, funding, etc. …)	What is the **current focus of the business strategy** (building partnerships with food chains, post and parcel companies, selling to the consumer, retail stores etc)	To what extent are autonomous ground vehicles for delivery **scalable** and what are factors influencing? (Pricing)	How would you describe the **impact of autonomous ground vehicles in the e-Commerce-Parcel industry** of the future? Which vehicles will be of the most value (droids, vans, parcel lockers)	How would you describe the **technological maturity** of autonomous ground delivery vehicles? (ready for take off, long way to go…)	What have been the **main improvements/technological components** which made the rise of droid startups in delivery so dynamic (LiDar, Computer vision advancements, Hardware, Sensors..)	What is your **experience of the consumers perceptions** - any barriers to overcome (are they afraid, do they like it)	What is the **regulatory status** in autonomous ground vehicles, especially on sidewalks?	How will the future look like/the implementation process?
Torsten Scholl Teleretail (CEO)	- The ideal reason is to create something new that will simplify transport in the future and increase the availability of transport capacity. - The goal is to create a universal software platform which let different vehicles fulfil their tasks autonomously, mainly transportation tasks	- Our focus is last mile, because it is the most complex part of the chain, as the environment has more influential factors compared to distance transportation and as it is more universally adaptable - At the moment we are restricted to drive publically because of the Wiener Konvention in EU, but as we observe it as a universal deployment of different nearfield operations, we can use the technology already in campus or industry environments - This will result in a higher value in the future in Europe than the transportation of a pizza or whatever for example	- Regulation, economical (scalability) but also the sole technological maturity is not developed enough - How to use the urban environment: development of concepts with elevator manufacturer	- Today is is more of a mixture between strategies as there are no vehicles so far which are really designed for it, such that we have to develop the vehicles ourselves - And our approach is that we decide with the customer about the transportation tasks (weight, volume, speed,etc.) and this serves as the basis for the development of a special vehicle - On the same page we try to find main components which are equal for different customers to break out of the specialized vehicle manufacturing but it is still too early stage.	- Not yet, only when full autonomy will be achieved a universal solution will evolve	- Work in conjunction with humans, it is just a better tool to make the job of deliverers faster and more efficient	- 90% autonomous driving so the technology is mature just that the supervisor (remotly monitoring in proximity) has to be checking on the robot they have to be there so far	- Technology is just a tool which we use in order to make deliveries cheaper and affordable where wages are too high that make delivery not possible or not scalable enough - Delivery could be expensive in the winter and we don't want to have human go through harsh weather or hazardous weather	- They interact with them a lot and really like them - We have a huge appeal from the community, they start taking pictures, even the kids		- Partnered with official authorities and they have given the green light so its up and running
PNS Delivery Bot Startup (Growth, Strategy and Marketing)	- create the infrastructure network of the future for delivery - make delivery more affordable and accessible	- Food focus as it is more feasible at the moment - In the US already activities on the streets but also closed campus environments - The expansion to several cities in the US went well and now going global also EU as the goal	- Depending on the region we need to comply with different authorities, multiple - Legal regulations are the major roadblocks	- App of the company has some restaurants listed, so it's a completely different food delivery application, some restaurants have a partnership, some don't - The bots are available at the restaurants (several hundreds robots) - Consumer pays a delivery fee (around 3€) - Competitors are entering the market but we share the vision of them and and we understood it's not about technology, it's about the social process around its adoption	- Vehicles are small and if there is more food demanded that does not fit in one there will be more bots, the bot itself cannot be adjusted	- Work in conjunction with humans, it is just a better tool to make the job of deliverers faster and more efficient	- 90% autonomous driving so the technology is mature just that the supervisor (remotly monitoring in proximity) has to be checking on the robot they have to be there so far	- Technology is just a tool which we use in order to make deliveries cheaper and affordable where wages are too high that make delivery not possible or not scalable enough - Delivery could be expensive in the winter and we don't want to have human go through harsh weather or hazardous weather	- They interact with them a lot and really like them - We have a huge appeal from the community, they start taking pictures, even the kids		- Partnered with official authorities and they have given the green light so its up and running

*PNS: prefers not to say

	Q1 Can you please shortly describe what your **company's objective** is?	Q2 What are the **company's activities in terms of last mile delivery**? (special category (food, groceries, parcel etc.)	Q3 What are the **main challenges** your company is currently facing to achieve the mission/objectives? (external:legal, customer perception; or internal: technological, funding, etc. …)	Q4 What is the **current focus of the business strategy** (building partnerships with food chains, post and parcel companies, selling to the consumer, retail stores etc)	Q5 To what extent are autonomous ground vehicles for delivery **scalable** and what are factors influencing? (Pricing)	Q6 How would you describe the **impact of autonomous ground vehicles in the e-Commerce-Parcel industry** of the future? Which vehicles will be of the most value (droids, vans, parcel lockers)	Q7 How would you describe the **technological maturity** of autonomous ground delivery vehicles? (ready for take off, long way to go…)	Q8 What have been the **main improvements/technological components** which made the rise of droid startups in delivery so dynamic (LiDar, Computer vision advancements, Hardware, Sensors..)	Q9 What is your **experience of the consumers perceptions** - any barriers to overcome (are they afraid, do they like it)	**Additional Q** What is the **regulatory status** in autonomous ground vehicles, especially on sidewalks?	How will the future look like/the implementation process?
PNS Corporate & Consumer Investment Bank (Relationship Director I Manufacturing, Transport & Logistics)	- investment bank	- involved occasionally in the funding of vehicles or assets that form a part of the last mile joruney - mixture of 3PL providers, last mile delivery providers, postal companies, full suite of logistics supply chain	- need for real estate (retail property prices are decreasing and logistics property prices are increasing): making it difficult for new entrants to come in to the last mile delivery market - next day delivery and timeslot delivery - legislation/regulation - key risk: technology is not proven (if we would take any residual value risk against those assets, the technology moves along so quickly, so what we finance today might not actually be worth anything in 2-3years time - user acceptability - somewhere like london a last mile delivery driver, he may actually drive 7km in a day, but walk 10 km and does the majority up and down the stairs: no capabilities to go upstairs if there is no lift...			- survey shows main investments in the next 3 years will be more software driven technologies, improving warehouse and transport management systems, to reduce empty backloads, cloud-services and data management etc - driver shortage in e.g. UK, simply not enough people to do this jobs	- ist not necessarily that it is not mature but if a company comes to me and want to have it financed solely because they are a last mile automated delivery company they become difficult to finance: other companies with similar technologies and you have to back the winner, we are not an equity provider but a dept provider, so our risk is a bit on the idea of predictable cashflows, which a startup would not necessarily have today - DHL etc. we could rely on the corporate risk rather than purely the technology		- if consumers will find it helpful to what they have presently then the takeup will be rapid - industry noise is to push back the next-day delivery and timeslot delivery but the genie is out of the bottle and the consumer knows what they want and the industry hast to adapt - so the consumer remains core	- key risk is regulation as of if an autonomous vehicle is involved in an accident or sort of, who is reliable for thath, what does that do with a companys value, brand etc. - change in regulation clarifies that risk and derisks the market	- in closed environments: see some of that happening in the client base, working on projects in closed campuses - ist a good method to get the door open for regulation and proof concept in a closed environment - mixture of speed of change but ultimately it will be a smooth transition with the first thing will be hub-to-hub journeys rather than the last mile
PNS Starship Technologies (Generic Q&A/not personal interview)	- world's leading autonomous delivery service provider - designed to manage local delivery of packages and FMCG (fast moving consumer goods including laundry, packages, food, groceries, flowers, etc.)	- Essentially Starship can deliver anything up to 10kg that can fit inside its delivery container such as parcels, groceries,food, laundry, medication, flower, etc. - The robot is designed to deliver goods on the last mile of the delivery journey – within suburban, residential areas. They currently deliver within a 2-mile radius but can go further - Any company that needs to deliver goods to consumers. The main three industries Starship is working with are – parcel delivery (every company from courier services to retailers), groceries (supermarkets) and food (takeaway food, restaurants) but we are aiming to expand further		- Pay per delivery for our B2C consumer service - Pay monthly for our B2B service, normally found on campuses where businesses would pay monthly for use of the robot, the maintenance, the operators etc.	- we run a commercial autonomous delivery service in a number of cities around the world on a daily basis, completing tens of thousands of deliveries to date. - Current prices range from $1-3 per delivery	- Sidewalks are the most underutilised piece of infrastructure is many cities and suburbs. It is much safer and more efficient for the robots to be on sidewalks because it acts like a pedestrian, and matches pedestrian speeds	- The robots can drive autonomously in pre-mapped areas. The mapping process is highly efficient and involves the robots under human control for the first runs. After the routes have been mapped, the robots can at any given time turn to human operators for assistance when making decisions in unexpected situations or when dealing with social interaction	- It uses a sensor suite for navigation, situational awareness and reaction controls. The GPS and CV based navigation uses proprietary maps and allows for 2 cm navigation precision - a mixture of GPS and Computer vision to pinpoint its exact location to the nearest inch - The robot has obstacle detection - It has a 'situational awareness bubble' around it - featuring either 9 or 10 cameras depending on the model, ultrasonic sensors, radars, neural networks and more to detect obstacles, whether that is a dog or a pedestrian/cyclist	- The robots have driven tens of thousands of miles now around the world and come into contact with millions of people. Surprisingly, around 70% of people don't pay attention to the robot. The robots are a part of daily life already. The remaining 30% are overwhelmingly positive.	- The laws and regulations governing The legality of The robot is different for each country around The world.	- Delivery drivers are still the most efficient method for the first 10-100 miles of the transportation process. Delivery drivers will work closely with our robots to ensure the entire delivery process becomes more efficient. We may even have delivery drivers picking up and dropping off robots in different neighborhoods

*PNS: prefers not to say

Appendix J: Interviews analysis: summaries of the findings

	Strategical direction (Q2, Q4 & Q6)	**Technology** (Q5, Q7 & Q8)	**Regulation** (Additional Questions)	**Consumer** (Q9)	**Implementation Challenges** (Q3)
Konstantin Lassning ARTI (CEO)	**Strategic direction**: focus on last mile in CEP industry and driven from the general technology possibly adaptable to different use cases **Current strategic focus**: not forseeable, partnerships with postal companies; for the future hybrid model with purchased services of the technology provider as industry is afraid of default risk **Impact on Parcel industry**: impact increases with level of autonomy, currently additional service rather than solving the challenge (replace main cost factor)	**Technological scalability:** depends on the economic setting (mainly labor costs) robots have to undercut the prices **Technological maturity**: Technology is ready given specific environments (closed campuses, piloting facilities), maturity high but still not economic enough although sensor prices decrease **Main technological components**: Sensors (laser scanners are too expensive) and the environment is highly dynamic and unpredictable	- Highly difficult, we already tried to launch a product, but it is a complete grey area in Austria, nobody is able to answer also of the federal authorities. Personal transportation and commercial goods are different settings but both lack in regulation - One opportunity is to be small enough to fall under toy regulations or the accompanying of a robot in proximity - SG has a regulation for punishment if a robot will be disturbed in their mission or delivery Complexity increases with level of autonomy which is why semi-autonomy is developed to roll out faster and the opportunity is in walking replacement	- Europe is more conservative and laugh at the technology and critical about the functionality - Fear of human replacement, which is not true in the cep industry as it is a reaction on the too fast market growth - Questions on door opening, steps, etc. but what is the status of the technology and where are the deliverers shortcomings - Expectations are really high on technology (need for a clarification on what can be done and what is not realistic)	full automation, navigation/routing, premapping of areas is timeintensive, different settings need different technolovial approaches
Damien Declercq Spring Mobility (CEO)	**Strategic direction**: using the technology for different use cases building a modular self driving vehicle **Current strategic focus**: market too early to set a strategic focus: jointly deployment of vehicles for different application, customer decides, at the moment a sweeper and parcel locker **Impact on Parcel Industry**: A lot of benefits to implement self-driving fleets but timing is an insercurity	**Technological scalability:** economies of scale will kick in soon with a production volum of hundreds already, currently companies operate with prototypes only; benefit for later entrants which can skip this phase (as seen in self driving shuttle with Olli, Navya, Easy Mile and Baidu) **Technological maturity:** high speed technological requirements are highly different from sidewalks, in closed environment the technology is ready and can be deployed **Main technological components:** Sensors have been around already a longer time, but the compuational power to process the sensor data and migrate different data formats (data fusion), costs of sensors decrease significantly		- pilot of self-driving shuttle showed that consumers dont even recognise that it is self-driving and there is increasing awareness and consciousness - not very afraif about consumers adoption, once it is there it will just be part of daily life - awareness work from a commercial/marketing perspective needs to be done but as consumers will see the vehicles around anywhere they will adapt quickly	Awareness and maturity of the solutions, Regulation
Torsten Scholl Teleretail (CEO)	**Strategic direction:** Last mile as a focus as it is most complex and adaptable but transportation of goods in the future has a higher value than current delivery of pizza **Current strategic focus:** mixture between strategies as vehicles have no dominant design and prototypes need to be developed. In cooperation with customer about transportation task - too early for commercialisation **Impact on Parcel industry:** high but not on sidewalks as the main deployment rather a testing field as regulaory framework is more liberal, suburban areas	**Technological scalability**: scalability will evolve only when full autonomy will be achieved **Technological maturity:** full autonomy only in closed environments as campuses or industrial sites, sidewalk robots are remotely controlled **Main technological components:** different sensors, but the highest safety standards are still very expensive, but with lower speed also cheaper sensors can be deployed (velodyne LiDar),	- Regulation is missing --> Insurance is missing --> company risks - US is pilot first than something happens, and the dispute and discussions begin: For example Arizona allowed self-driving vehicles but companies take the risks themselves, they have to pose a deposit of 5M$ - EU regulated and thought through until the end before something is going to be tested - Regulation is very slow although there are some initiatives of countries - Germany has strict sidewalk regulation as part of the traffic /road regulations, US the city or village can allow self-driving vehicles on sidewalks but street is also federal - Playground now in non-public environments as more freely regulated	- ESA-supported feasibility study to deliver wines for a short distance with a lot of surveys in consumer expectations, how should it look like, be opened, where should it drive, what is the value - Results: not too silent, to perceive the robot; easy handling, people just sit on it - Consumer did not have doubts for safety reasons, at least in Europe as they seek for replacement of easy task - In the US there is more aggression which resonates in different issues, as for example delivery jobs are more attractive than in EU	Regulation and economical scalability, technological maturity, infrastructural challenges

	Strategical direction (Q2, Q4 & Q6)	**Technology** (Q5, Q7 & Q8)	**Regulation** (Additional Questions)	**Consumer** (Q9)	**Implementation Challenges** (Q3)
PNS Delivery Bot Startup (Growth, Strategy and Marketing)	**Strategic direction:** Generally everything which can be delivered and fits in the compartment **Current strategic focus:** food because of ist feasibility, and on closed campuses or some cities in the US, Company provides the bots to the restaurant and bot delivery only via the companys app **Impact on Parcel delivery:** no clear statement	**Technological scalability**: technology as a tool where deliveries can be made cheaper and affordable (wages are too high or in harsh environments like winter) **Technological maturity**: technology is mature enough and drives 90% autonomous, however remote monitoring is still necessary by a supervisor **Main technological components:** -	- Partnered with official authorities and they have given the green light so its up and running	- They interact with them a lot and really like them - We have a huge appeal from the community, they start taking pictures, even the kids	Regulation
PNS Corporate & Consumer Investment Bank (Relationship Director I Manufacturing, Transport & Logistics)	- involved occasionally in the funding of vehicles or assets that form a part of the last mile joruney - mixture of 3PL providers, last mile delivery providers, postal companies, full suite of logistics supply chain	**Technological maturity:** ist not necessarily that it is not mature but if a company comes to me and want to have it financed solely because they are a last mile automated delivery company they become difficult to finance: other companies with similar technologies and you have to back the winner, we are not an equity provider but a dept provider, so our risk is a bit on the idea of predictable cashflows, which a startup would not necessarily have today - DHL etc. we could rely on the corporate risk rather than purely the technology	- key risk is regulation as of if an autonomous vehicle is involved in an accident or sort of, who is reliable for thath, what does that do with a companys value, brand etc. - change in regulation clarifies that risk and derisks the market - in closed environments: see some of that happening in the client base, working on projects in closed campuses - ist a good method to get the door open for regulation and proof concept in a closed environment - mixture of speed of change but ultimately it will be a smooth transition with the first thing will be hub-to-hub journeys rather than the last mile"	- if consumers will find it helpful to what they have presently then the takeup will be rapid - industry noise is to push back the next-day delivery and timeslot delivery but the genie is out of the bottle and the consumer knows what they want and the industry hast to adapt - so the consumer remains core	Infrastructural challenges, regulation, consumer acceptability, technological maturity

*PNS: Prefers not to say

PNS Starship Technologies (Generic Q&A/not personal interview)	**Strategic direction:** Generally everything which fits the compartment **Current strategic focus:** parcel delivery, food and groceries, pay per delivery (each delivery costs 1.99$) **Impact on parcel delivery:** sidewalk is underutilised, safe and efficient environment for operating the robots	**Technological scalability:** a number of cities already in service, over 50k global deliveries already **Technological maturity:** in pre mapped areas the robots drive autonomously, human operators for unexpected situations **Main technological components:** GPS, Computer vision, obstacle detection, cameras, utrasonic sensors, radars	- The laws and regulations governing The legality of The robot is different for each country around The world.	- The robots have driven tens of thousands of miles now around the world and come into contact with millions of people. Surprisingly, around 70% of people don't pay attention to the robot. The robots are a part of daily life already. The remaining 30% are overwhelmingly positive.	

*PNS: Prefers not to say

Appendix K: Online survey questionnaire

INTRODUCTION

Dear Participant,

My name is Daniel Barthuly and I am a master student of International Management at Catolica Lisbon School of Business and Economics. In this research, I am analyzing the consumer's willingness to accept an innovative way of delivery. You are invited to contribute to this research by participating in this quick survey, which will take up less than 8 minutes of your time.

Thank you!

PART 1

#	Question	Scale
1	On average, how frequently do you order something online for delivery per month? (including all categories of goods, such as food, clothing, electronics, books, home wares...)	Scale (0-15, 15+)
2	Please think of your last orders for delivery. Please rank the delivery options below according to your chosen preferences.	Ranking (home, workplace, parcel locker, pickup shop (postal company), pysical store (retailer))
3	Have you ever heard of autonomous/self-driving vehicles before?	binary (yes/no)

only presented if previous answer was no:

Please read the following description in order to continue the survey

An autonomous/self-driving vehicle will be a vehicle that is capable of sensing its surroundings and navigating without human intervention. Autonomous vehicles would use hardware such as radar, GPS, computer vision, and advanced control systems to survey the vehicle's surroundings, identify traffic patterns and potential obstacles, and steer the vehicle from one location to another without driver involvement.

The benefits of autonomous vehicles among others are:
reduced accidents
reduced traffic congestion
reduced travel time and transportation costs
lower fuel consumption
more efficient last-mile activites

#	Question	Scale
4	Please self-assess your level of knowledge with the concept of autonomous/self-driving vehicles	Ordinal (1=Poor, 2=Fair, 3=Good, 4=Excellent)

PART 2

#	Question	Scale
5	On a scale from 1 (strongly disagree) to 7 (strongly agree), please indicate your level of agreement	
OPT	Technology gives me more freedom of mobility Technology makes me more productive in my personal life New technologies contribute to a better quality of life Smart devices help me to optimise my life	7-Point Likert
INN	Other people come to me for advice on new technologies I can usually figure out new high-tech products and services without help from others I keep up with the latest technological developments in my areas of interest I use chatbots to interact with customer service	
DIS	Technology always seems to fail at the worst possible time Many new technologies have health or safety risks that are not discovered until after people have used them Technical support is not helpful because they don't use understandable words to explain New technologies take jobs from humans	
INS	People are too dependent on technology to do things for them New technology makes it too easy for governments and companies to spy on people Technology lowers the quality of relationships by reducing personal interaction Increasing smart phone usage concerns me	

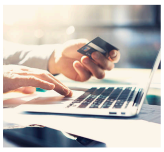
Please read the following description, which is crucial in order to continue with the survey.

The new concept of autonomous ground vehicles for home delivery will increase the service quality of online customers. These vehicles will be used to deliver parcels, food and groceries and will drive electrically and autonomously on sidewalks with a walking speed. This enables a more convenient and flexible service, as deliveries can be carried out also during evenings and weekends. The on-demand delivery will allow you to get your parcel delivered the same day without the need to go to a pickup shop or locker, when you are not at home.

The customers benefits are:
no walking to pick up your parcel
no carrying of heavy parcels
no dependency on opening hours
no waiting in lines

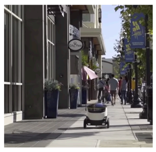
The following Picture describes the customer journey in short.

Buy something online



Pick home delivery by robot

The ordered item will drive autonomously to your home



Get your ordered item delivered flexibly to your home

PART 3

#	Question	Scale
6	On a scale from 1 (strongly disagree) to 7 (strongly agree), please indicate your level of agreement	
A	I feel **happy** about the above shown delivery possibility I feel **curious** about the above shown delivery possibility I feel **scared** about the above shown delivery possibility I feel **alarmed** about the above shown delivery possibility I feel **angry** about the above shown delivery possibility	7-Point Likert
	other feelings	open entry
7	Please indicate your level of agreement on the **usage of the autonomous ground delivery vehicle**s on a scale from 1 (strongly disagree) to 7 (strongly agree).	
BI	I would consider to use autonomous ground robots for my next delivery because of an **increased level of convenience and flexibility**. I would consider to use autonomous ground robots for my next delivery because of an **better environmental impact**. I would consider to use autonomous ground robots for my next delivery because of an **like to interact with an robot**. I would consider to use autonomous ground robots for my next delivery because of **lower delivery costs**. I would **not consider** to use autonomous ground robots for my next delivery because **I care about the human worker**. I would **not consider** to use autonomous ground robots for my next delivery because they would **annoy me on the sidewalks.** I would **not consider** to use autonomous ground robots for my next delivery because **safety and security reasons**.	7-Point Likert
	other	open entry
8	On a scale from 1 (extremely useless) to 7 (extremely useful), please indicate your opinion on the **overall usefulness of autonomous ground vehicles for delivery**	
PU	Autonomous ground delivery vehicles for delivery	7-Point Likert
9	Please describe your first thoughts on the above shown concept for autonomous ground delivery (including misunderstandings, concerns, benefits and any other thoughts)	open entry

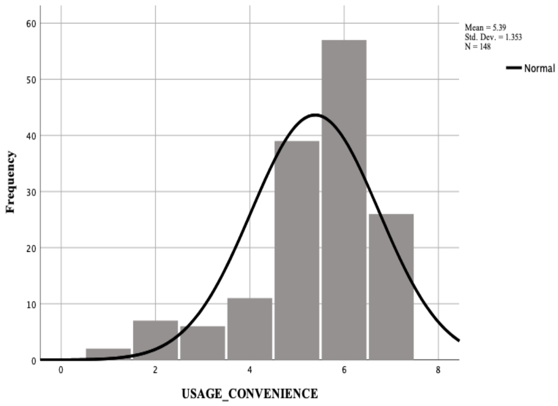
PART 4

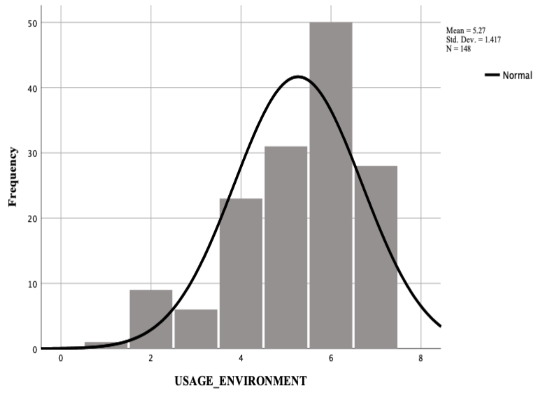
#	Question	Scale
10	Which category below includes your age?	nominal (below 18, 18-24, 25-34, 35-50, 50+)
11	What is your gender?	nominal (female, male, prefer not to say)
12	What is your current occupation?	nominal (unemployed, student, employed, retired, other)
13	What is your nationality?	nominal (List of countries)

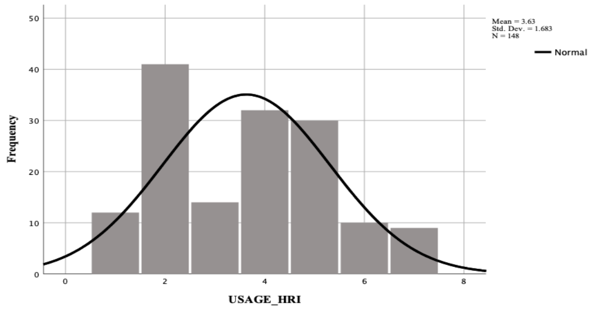
Appendix L: Delivery Behaviour frequency tables

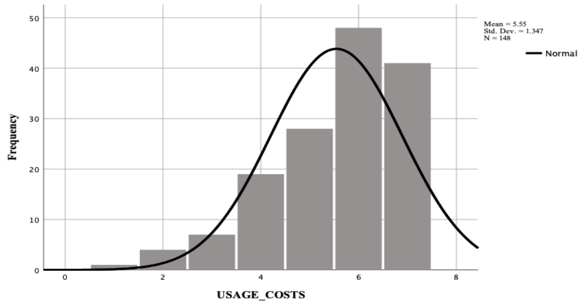
		Frequency	Percent	Valid Percent	Cumulative Percent
Frequency of monthly deliveries	0	4	2.7	2.7	2.7
	1	32	21.6	21.6	24.3
	2	28	18.9	18.9	43.2
	3	33	22.3	22.3	65.5
	4	15	10.1	10.1	75.7
	5	11	7.4	7.4	83.1
	6	9	6.1	6.1	89.2
	7	4	2.7	2.7	91.9
	8	6	4.1	4.1	95.9
	9	3	2.0	2.0	98.0
	10	2	1.4	1.4	99.3
	12	1	.7	.7	100.0
Delivered to home (Ranking)	1	111	75	75	75
	2	27	18.2	18.2	93.2
	3	8	5.4	5.4	98.6
	4	1	.7	.7	99.3
	5	1	.7	.7	100.0
Delivered to work (Ranking)	1	22	14.9	14.9	14.9
	2	53	35.8	35.8	50.7
	3	25	16.9	16.9	67.6
	4	18	12.2	12.2	79.7
	5	30	20.3	20.3	100.0
Delivered to a parcel locker (Ranking)	1	9	6.1	6.1	6.1
	2	22	14.9	14.9	20.9
	3	41	27.7	27.7	48.6
	4	40	27.0	27.0	75.7
	5	36	24.3	24.3	100.0
Delivered to a pickup shop (Ranking)	1	5	3.4	3.4	3.4
	2	29	19.6	19.6	23.0
	3	42	28.4	28.4	51.4
	4	53	35.8	35.8	87.2
	5	19	12.8	12.8	100.0
Delivered to a physical store (Ranking)	1	1	.7	.7	.7
	2	17	11.5	11.5	12.2
	3	32	21.6	21.6	33.8
	4	36	24.3	24.3	58.1
	5	62	41.9	41.9	100.0

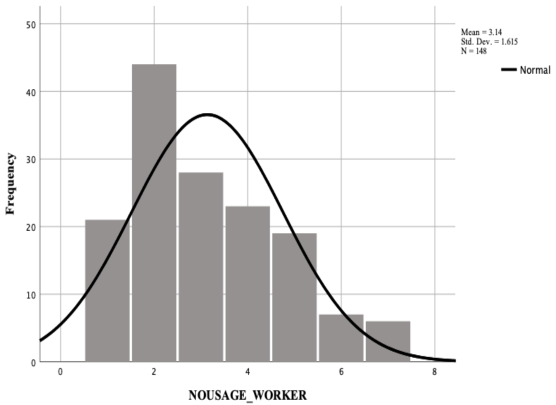
Appendix M: Histograms for individual usage items and perceived usefulness

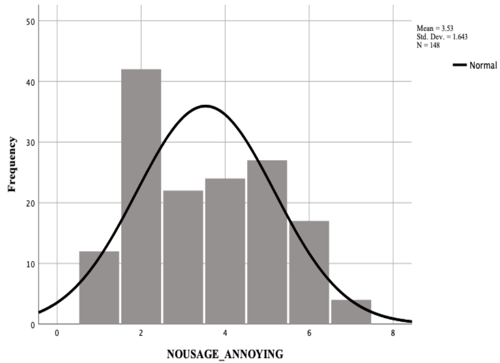


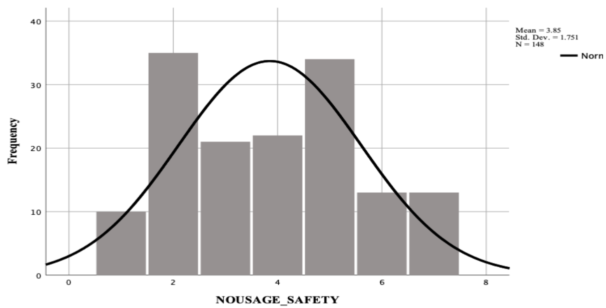


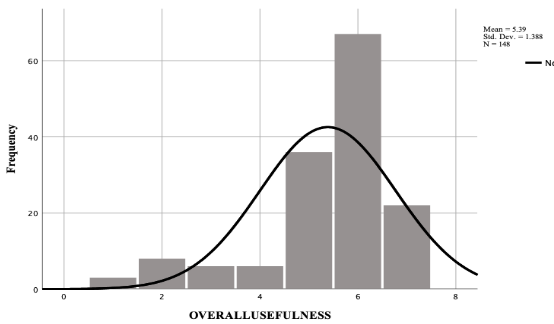












Appendix N: Online survey open text entry data analysis

Statements	Safety	Proof of concept	Consumer Interaction	Robot specifications	Sidewalk	Environment	Jobs	Convenience	Environment	Jobs	Fun
confused											
I feel it's nice but I would be afraid someone steals it on the way to me	x										
Great concept of which the implementation will be interesting to observe especially inlcuding it into daily traffic.				x	x						
Suspicious											
When does it arrive?			x								
The delivery items could be stollen on the way to the recipient.	x										
Interesting topic. I would like to know more how the robot works in traffic, for example crossing a road without traffic lights. Another thing that came to my mind was, if the goods delivered can be easily stolen. This concept might have a lot to offer, when thought out carefully. Good luck with your thesis!	x			x	x						
curious if it works		x									
It is fine for big cities and places with developed infrastucture. Some places and streets in Russia will be unsuitable for this type of delivery (high curbs, poor road surface and so on).		x									
Faster than human delivery								x			
unsure, Seems fast and less costly, however I would be worried about the safety of the package	x							x			
Super cool, but my concern is how well they can adapt to streets		x									
Great idea, but first details of implementation have to prove the concept		x									
I thought the robots would be bigger so that they can do several deliveries at once. Also, I did not know they would be driving on the sidewalk which would be more annoying for pedestrians. However, I like the flexibility it offers for a 24/7 delivery to				x				x			
Wondering how they would navigate crowded sidewalks, crossings, etc...				x	x						
concerns: increase in traffic as appears to be the most comfortable delivery option, environmental impact (energy mix that is used)		x				x					
Logistical concerns come up when I think about it, the interaction on the pedestrian walks. However, we need a better and more environmentally friendly solution for all the deliveries which take place each and every day. So I see this as a great opportunity, not to mention the increasing convenience factor.					x			x	x		
new, innovative, great advantageous compared to other delivery services											
Concerns on the ease of someone taking your parcel	x										
How smooth will the interaction with humans (e.g. pedestrians) be?			x								
1. Who is receiving the order? Is there something like a mailbox or do I have to be at home? 2. Why do they drive on the sidewalk? Cant they drive on the road like the delivery cars?			x		x						
because of a likely more precise delivery time/ schedule. Hence, better planning possible at my side								x			
Sounds like a cool idea but I‚Äôm unsure about the feasibility from a legal and operational point of view		x									
I see the issue of overloading the pedestrian lanes, which will likely motivate the pedestrians to walk on the car or bike lanes instead (collision dangers)					x						
There are no misunderstandingsand very low concerns											
Crazy , bizarr and unusual but helpful and funny											x
A great misunderstanding is, in my opinion, that technology development will steal peoples jobs. In contrast, I think through advanced technology people are given the possibility to spend their time on things that make them happy, with friends and family (And not in delivering parcels). The human work will always be irreplaceable.										x	
cool											
Easyly stolen	x										
Nice feature											
I would be very worried that the contents of the vehicle could get stolen or damaged. It would not work for people who live in rural areas.	x	x									
Interesting											
Is it really more environmentally friendly though?						x					
I think it is an interesting concept, which would increase user convenience and reduce environmental footprint due to decreased CO2 emissions from vehicles. However, I feel there are some aspects that are unclear. How safe is it for this vehicle to move on the sidewalk(without injuring pedestrians, especially little kids). What happens if the user is not home at that particular moment? Also, I feel that a great number of delivery workers would lose their jobs, so they should be taken care of.	x		x		x		x	x	x		

Statements	Safety	Proof of concept	Consumer Interaction	Robot specifications	Sidewalk	Environment	Jobs	Convenience	Environment	Jobs	Fun
How can we make sure no one steals one of the robot and its content. What if someone takes it and breaks it?	x	x									
The only doubt i would have would be the risk of the robot being destroyed and how the law would handle the situation and who should be compensated or punished for the damage created.	x										
First, the idea seems to be a bit scary and it might also be the case that jobs will be taken away. On the other hand, new jobs will be created in the tech sector and customers will be able to receive their parcel when ever they want- which is nice.										x	
The shown concept looks convenient to use but I think it's not possible to use these robots on a big scale on Wich we are now.		x						x			
I had a good feeling because I had the feeling it makes my life easier and I don't have to worry about the delivery and don't have do be concerned about picking it up somewhere								x			
Innovative way for delivery, probably faster and maybe also more reliable than by human. Hard to imagine that the concept works in a Status Quo environment - more intelligent & connected traffic systems will be needed.		x						x			
I would consider to use one because I am concerned about working conditions of delivery workers I think it gets interesting (also economically valuable) only when this is adopted by the a large amount of people in a common physical area. Then it might save a lot of time, money and will have a positive impact on the Environment.								x	x	x	
I think the biggest obstacle will become space on the sidewalks.					x						
The concept makes me worried about the jobs it ill jeopardise for actual human delivery workers.							x				
Use autonomous because humans dont have to do repetitive jobs										x	
security concerns	x										
I would need a better understanding of how I would be the only access the goods, maybe even try it with lower valued goods	x										
It looks useful and flexible but might be prone to safety	x										
For me, it is crucial to know about the environmental impact when choosing autonomous ground delivery. Reducing emission and pollution has a higher priority for me, than reducing the delivery times (which are already good).						x					
Autonomous delivery will improve overall economics for lowering cost and enabling new types of business. However it will acceralte the unemployment rate, so governments mught consider Universal Basic Income proposal (example: everyone gets 1.000/month whoever is the person rich or poor)							x				
Need to be home when they arrive			x								
Skeptical											
First thought: great!											
Looks like a convenient way to deliver since it's delivering on-demand, independently of working hours of usual delivery services.								x			
Concern that someone can easily steal the robot (including my order).	x										
Someone could just steal whatever is inside it and they have a huge amount of health and safety issues involved with them driving around	x										
Good idea but might be annoying on the sidewalks					x						
If the technology is developed enough and there are no bugs - the robot actually brings me my package in good condition and on time - that works and is useful!		x									
I‚Äôm concerned about the idea that someone can steal my delivery before it gets to me or that the technology fails and the delivery takes even longer I want to see it happen today so we can discuss tomorrow and optimize the day after. However, I do live in Germany. It will take us four more years than the rest of Europe to get there	x										
Looks great											
Most of the time, the consumers are not waiting for the things they ordered at home. Due to the capacity of the robots, only a few packages can be taken, so if the costumer is not at home, it would be a bigger waste, as if it is done by the delivery truck that has a bigger capacity.				x							
Concerns if package security, far too easy to steal.	x										
Sceptical											
Excited											
Cool new service. Would love to try it!											
lack of trust regarding the use (in terms of the robot making errors / delivering to wrong place / not opening the container / higher margin for error / ability to get abused or hacked / ability for people to steal your delivery / inconvenience / slow / unnecessary / doesn't actually improve things but rather makes them more complicated for little benefit)	x		x								
Might be overseen by pedestrians and cars	x				x						
good idea, already knew it before											
does not matter!											
Summary	19	11	6	5	10	3	3	11	3	4	1

Appendix O: Principal Component Analysis Behavioral Intention (BI)

Component Matrix[a]

	Component	
	1	2
USAGE_CONVENIENCE	0,764	-0,131
NOUSAGEWORKER_R	0,751	0,093
USAGE_COSTS	0,676	-0,398
USAGE_ENVIRONMENT	0,527	-0,458
USAGE_HRI	0,527	-0,194
NOUSAGESAFETY_R	0,501	0,625
NOUSAGEANNOYING_R	0,555	0,594

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Pattern Matrix[a]

	Component	
	1	2
USAGE_COSTS	0,800	-0,064
USAGE_ENVIRONMENT	0,726	-0,188
USAGE_CONVENIENCE	0,682	0,226
USAGE_HRI	0,542	0,059
NOUSAGEWORKER_R	0,517	0,429
NOUSAGESAFETY_R	-0,047	0,813
NOUSAGEANNOYING_R	0,017	0,808

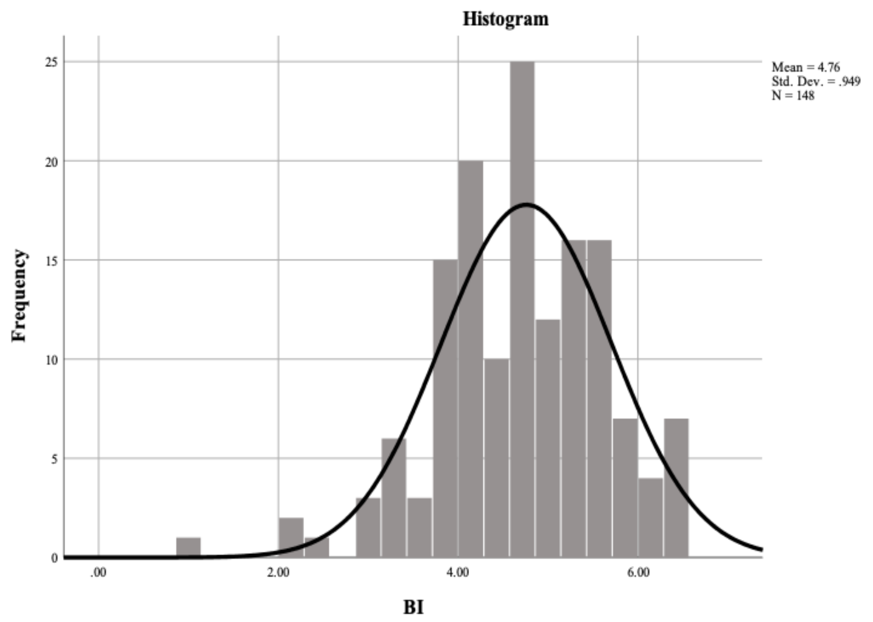
Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Appendix P: Variables and measures

Variable		Variable Item	Specifications
A	A1	I feel **happy** about the above shown delivery possibility	
	A2	I feel **curious** about the above shown delivery possibility	
	A3	I feel **scared** about the above shown delivery possibility	reverse coded
	A4	I feel **alarmed** about the above shown delivery possibility	reverse coded
	A5	I feel **angry** about the above shown delivery possibility	reverse coded
BI	BI1	I would consider to use autonomous ground robots for my next delivery because of an **increased level of convenience and flexibility**.	
	BI2	I would consider to use autonomous ground robots for my next delivery because of an **better environmental impact**.	
	BI3	I would consider to use autonomous ground robots because of the **interaction with a robot**	
	BI4	I would consider to use autonomous ground robots for my next delivery because of **lower delivery costs**.	
	BI5	I would **not consider** to use autonomous ground robots for my next delivery because **I care about the human worker**.	reverse coded
	BI6	I would **not consider** to use autonomous ground robots for my next delivery because they would **annoy me on the sidewalks.**	reverse coded
	Bi7	I would **not consider** to use autonomous ground robots for my next delivery because **safety and security reasons**.	reverse coded
TRI		*includes OPT, INN, DIS (reverse coded), INS (reverse coded)*	
OPT	OPT1	Technology gives me more freedom of mobility	
	OPT2	Technology makes me more productive in my personal life	
	OPT3	New technologies contribute to a better quality of life	
	OPT4	Smart devices help me to optimise my life	
INN	INN1	Other people come to me for advice on new technologies	
	INN2	I can usually figure out new high-tech products and services without help from others	
	INN3	I keep up with the latest technological developments in my areas of interest	
DIS	DIS1	Technology always seems to fail at the worst possible time	
	DIS2	Many new technologies have health or safety risks that are not discovered until after people have used them	
	DIS3	Technical support is not helpful because they don't use understandable words to explain	
INS	INS1	People are too dependent on technology to do things for them	
	INS2	New technology makes it too easy for governments and companies to spy on people	
	INS3	Technology lowers the quality of relationships by reducing personal interaction	
	INS4	Increasing smart phone usage concerns me	

Appendix Q: Test for Normality with Histogram and Descriptives for Behavioral Intent (BI)



Tests of Normality						
	Kolmogorov-Smirnova			Shapiro-Wilk		
BI	Statistic	df	Sig.	Statistic	df	Sig.
	.069	148	.080	.976	148	.010

a Lilliefors Significance Correction

Descriptives			Statistic	Std. Error
BI	Mean		4.7587	.0779
	95% Confidence Interval for Mean	Lower Bound	4.605	
		Upper Bound	4.913	
	5% Trimmed Mean		4.788	
	Median		4.857	
	Variance		.8999	
	Std. Deviation		.9486	
	Minimum		1	
	Maximum		6.5714	
	Range		5.5714	
	Interquartile Range		1.2857	
	Skewness		-.5265	.1993
	Kurtosis		1.008	.3961

Appendix R: Correlation Matrix of all relevant variables

		BI	***PU***	***A***	***TRI***	***OPT***	***INN***	***DIS***	***INS***
BI	Pearson Correlation	1	.450**	.642**	.521**	.438**	.354**	-.263**	-.285**
	Sig. (2-tailed)		0,000	0,000	0,000	0,000	0,000	0,001	0,000
	N	148	148	148	148	148	148	148	148
PU	Pearson Correlation	**.450****	1	.457**	.231**	.229**	.218**	-0,079	-0,057
	Sig. (2-tailed)	0,000		0,000	0,005	0,005	0,008	0,340	0,491
	N	148	148	148	148	148	148	148	148
A	Pearson Correlation	**.642****	**.457****	1	.543**	.477**	.370**	-.276**	-.275**
	Sig. (2-tailed)	0,000	0,000		0,000	0,000	0,000	0,001	0,001
	N	148	148	148	148	148	148	148	148
TRI	Pearson Correlation	**.521****	.231**	.543**	1	.664**	.666**	-.624**	-.595**
	Sig. (2-tailed)	0,000	0,005	0,000		0,000	0,000	0,000	0,000
	N	148	148	148	148	148	148	148	148
OPT	Pearson Correlation	**.438****	.229**	.477**	.664**	1	.395**	-0,141	-.232**
	Sig. (2-tailed)	0,000	0,005	0,000	0,000		0,000	0,087	0,005
	N	148	148	148	148	148	148	148	148
INN	Pearson Correlation	**.354****	.218**	.370**	.666**	.395**	1	-0,130	-0,045
	Sig. (2-tailed)	0,000	0,008	0,000	0,000	0,000		0,116	0,589
	N	148	148	148	148	148	148	148	148
DIS	Pearson Correlation	**-.263****	-0,079	-.276**	-.624**	-0,141	-0,130	1	.328**
	Sig. (2-tailed)	0,001	0,340	0,001	0,000	0,087	0,116		0,000
	N	148	148	148	148	148	148	148	148
INS	Pearson Correlation	**-.285****	-0,057	-.275**	-.595**	-.232**	-0,045	.328**	1
	Sig. (2-tailed)	0,000	0,491	0,001	0,000	0,005	0,589	0,000	
	N	148	148	148	148	148	148	148	148

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix S: Multiple Regression Results SPSS Output

Correlations

		BI	PU	A	TRI	OPT	INN	DIS	INS	AGE	GENDER	OCCUPATION	AV KNOWLEDGE	DF
Pearson Correlation	BI	1,000	0,443	0,643	0,511	0,427	0,345	-0,256	-0,276	0,023	-0,049	0,024	-0,114	0,194
	PU	0,443	1,000	0,455	0,220	0,220	0,211	-0,073	-0,049	0,023	0,045	0,063	0,027	0,241
	A	0,643	0,455	1,000	0,543	0,475	0,367	-0,274	-0,272	0,090	-0,091	0,006	0,006	0,290
	TRI	0,511	0,220	0,543	1,000	0,657	0,662	-0,623	-0,591	0,105	-0,210	-0,106	-0,238	0,275
	OPT	0,427	0,220	0,475	0,657	1,000	0,388	-0,134	-0,224	0,144	-0,158	-0,020	0,105	0,194
	INN	0,345	0,211	0,367	0,662	0,388	1,000	-0,124	-0,037	-0,082	-0,289	-0,005	-0,325	0,289
	DIS	-0,256	-0,073	-0,274	-0,623	-0,134	-0,124	1,000	0,324	-0,145	0,079	0,111	0,229	-0,077
	INS	-0,276	-0,049	-0,272	-0,591	-0,224	-0,037	0,324	1,000	-0,099	-0,028	0,142	0,083	-0,118
	AGE	0,023	0,023	0,090	0,105	0,144	-0,082	-0,145	-0,099	1,000	-0,112	-0,222	-0,048	0,142
	GENDER	-0,049	0,045	-0,091	-0,210	-0,158	-0,289	0,079	-0,028	-0,112	1,000	-0,041	0,147	-0,133
	OCCUPATION	0,024	0,063	0,006	-0,106	-0,020	-0,005	0,111	0,142	-0,222	-0,041	1,000	0,025	-0,188
	AVKNOWLEDGE	-0,114	0,027	0,006	-0,238	0,105	-0,325	0,229	0,083	-0,048	0,147	0,025	1,000	-0,145
	DF	0,194	0,241	0,290	0,275	0,194	0,289	-0,077	-0,118	0,142	-0,133	-0,188	-0,145	1,000
Sig. (1-tailed)	BI		0,000	0,000	0,000	0,000	0,000	0,001	0,000	0,389	0,279	0,385	0,084	0,009
	PU	0,000		0,000	0,004	0,004	0,005	0,189	0,277	0,389	0,295	0,225	0,372	0,002
	A	0,000	0,000		0,000	0,000	0,000	0,000	0,000	0,139	0,137	0,473	0,473	0,000
	TRI	0,000	0,004	0,000		0,000	0,000	0,000	0,000	0,102	0,005	0,101	0,002	0,000
	OPT	0,000	0,004	0,000	0,000		0,000	0,053	0,003	0,041	0,028	0,404	0,103	0,009
	INN	0,000	0,005	0,000	0,000	0,000		0,067	0,328	0,162	0,000	0,476	0,000	0,000
	DIS	0,001	0,189	0,000	0,000	0,053	0,067		0,000	0,040	0,169	0,090	0,003	0,177
	INS	0,000	0,277	0,000	0,000	0,003	0,328	0,000		0,116	0,367	0,043	0,159	0,077
	AGE	0,389	0,389	0,139	0,102	0,041	0,162	0,040	0,116		0,088	0,003	0,282	0,043
	GENDER	0,279	0,295	0,137	0,005	0,028	0,000	0,169	0,367	0,088		0,313	0,038	0,054
	OCCUPATION	0,385	0,225	0,473	0,101	0,404	0,476	0,090	0,043	0,003	0,313		0,383	0,011
	AVKNOWLEDGE	0,084	0,372	0,473	0,002	0,103	0,000	0,003	0,159	0,282	0,038	0,383		0,039
	DF	0,009	0,002	0,000	0,000	0,009	0,000	0,177	0,077	0,043	0,054	0,011	0,039	
N	BI	147	147	147	147	147	147	147	147	147	147	147	147	147
	PU	147	147	147	147	147	147	147	147	147	147	147	147	147
	A	147	147	147	147	147	147	147	147	147	147	147	147	147
	TRI	147	147	147	147	147	147	147	147	147	147	147	147	147
	OPT	147	147	147	147	147	147	147	147	147	147	147	147	147
	INN	147	147	147	147	147	147	147	147	147	147	147	147	147
	DIS	147	147	147	147	147	147	147	147	147	147	147	147	147
	INS	147	147	147	147	147	147	147	147	147	147	147	147	147
	AGE	147	147	147	147	147	147	147	147	147	147	147	147	147
	GENDER	147	147	147	147	147	147	147	147	147	147	147	147	147
	OCCUPATION	147	147	147	147	147	147	147	147	147	147	147	147	147
	AVKNOWLEDGE	147	147	147	147	147	147	147	147	147	147	147	147	147
	DF	147	147	147	147	147	147	147	147	147	147	147	147	147

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	A		Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	TRI		Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	PU		Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a. Dependent Variable: BI

Descriptive Statistics

	Mean	Std. Deviation	N
BI	4,7473	0,94170	147
PU	5,37	1,386	147
A	5,4435	0,97574	147
TRI	4,4541	0,63330	147
OPT	5,6446	0,86202	147
INN	4,9615	1,18368	147
DIS	3,8118	1,01215	147
INS	4,9779	0,93355	147
AGE	2,86	0,737	147
GENDER	1,39	0,516	147
OCCUPATION	2,67	0,655	147
AVKNOWLEDGE	2,36	1,122	147
DF	3,31	2,375	147

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.643[a]	0,413	0,409	0,72378	
2	.671[b]	0,450	0,443	0,70292	
3	.694[c]	0,481	0,470	0,68532	1,957

a. Predictors: (Constant), A

b. Predictors: (Constant), A, TRI

c. Predictors: (Constant), A, TRI, PU

d. Dependent Variable: BI

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	53,513	1	53,513	102,151	.000[b]
	Residual	75,960	145	0,524		
	Total	129,472	146			
2	Regression	58,322	2	29,161	59,018	.000[c]
	Residual	71,150	144	0,494		
	Total	129,472	146			
3	Regression	62,309	3	20,770	44,222	.000[d]
	Residual	67,163	143	0,470		
	Total	129,472	146			

a. Dependent Variable: BI

b. Predictors: (Constant), A

c. Predictors: (Constant), A, TRI

d. Predictors: (Constant), A, TRI, PU

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	1,370	0,339		4,035	0,000	0,699	2,041			
	A	0,620	0,061	0,643	10,107	0,000	0,499	0,742	0,643	0,643	0,643
2	(Constant)	0,504	0,431		1,171	0,244	-0,347	1,356			
	A	0,500	0,071	0,518	7,046	0,000	0,360	0,641	0,643	0,506	0,435
	TRI	0,341	0,109	0,229	3,120	0,002	0,125	0,557	0,511	0,252	0,193
3	(Constant)	0,228	0,431		0,529	0,598	-0,624	1,079			
	A	0,410	0,076	0,425	5,402	0,000	0,260	0,560	0,643	0,412	0,325
	TRI	0,352	0,107	0,237	3,301	0,001	0,141	0,563	0,511	0,266	0,199
	PU	0,134	0,046	0,197	2,914	0,004	0,043	0,225	0,443	0,237	0,175

a. Dependent Variable: BI

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	PU	.189[b]	2,707	0,008	0,220	0,793
	TRI	.229[b]	3,120	0,002	0,252	0,705
	OPT	.157[b]	2,200	0,029	0,180	0,774
	INN	.126[b]	1,861	0,065	0,153	0,865
	DIS	-.087[b]	-1,316	0,190	-0,109	0,925
	INS	-.110[b]	-1,668	0,097	-0,138	0,926
	AGE	-.035[b]	-0,544	0,587	-0,045	0,992
	GENDER	.010[b]	0,153	0,878	0,013	0,992
	OCCUPATION	.021[b]	0,324	0,747	0,027	1,000
	AVKNOWLEDGE	-.118[b]	-1,866	0,064	-0,154	1,000
	DF	.008[b]	0,121	0,904	0,010	0,916
2	PU	.197[c]	2,914	0,004	0,237	0,792
	OPT	.054[c]	0,651	0,516	0,054	0,548
	INN	.005[c]	0,063	0,950	0,005	0,561
	DIS	.047[c]	0,592	0,555	0,049	0,606
	INS	.001[c]	0,007	0,994	0,001	0,647
	AGE	-.048[c]	-0,772	0,441	-0,064	0,987
	GENDER	.049[c]	0,771	0,442	0,064	0,955
	OCCUPATION	.046[c]	0,744	0,458	0,062	0,983
	AVKNOWLEDGE	-.068[c]	-1,055	0,293	-0,088	0,918
	DF	-.022[c]	-0,335	0,738	-0,028	0,896
3	OPT	.048[d]	0,587	0,558	0,049	0,547
	INN	-.016[d]	-0,202	0,840	-0,017	0,556
	DIS	.036[d]	0,466	0,642	0,039	0,605
	INS	-.017[d]	-0,228	0,820	-0,019	0,643
	AGE	-.045[d]	-0,741	0,460	-0,062	0,987
	GENDER	.033[d]	0,525	0,600	0,044	0,947
	OCCUPATION	.035[d]	0,579	0,563	0,049	0,979
	AVKNOWLEDGE	-.071[d]	-1,136	0,258	-0,095	0,917
	DF	-.048[d]	-0,742	0,459	-0,062	0,880

a. Dependent Variable: BI

b. Predictors in the Model: (Constant), A

c. Predictors in the Model: (Constant), A, TRI

d. Predictors in the Model: (Constant), A, TRI, PU

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	2,5168	6,0008	4,7530	0,65474	148
Residual	-2,31619	2,05462	0,00566	0,67943	148
Std. Predicted Value	-3,414	1,919	0,009	1,002	148
Std. Residual	-3,380	2,998	0,008	0,991	148

a. Dependent Variable: BI