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Tackling Trends of Door-to-Door Air Travel in the European Market

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Abstract

Door-to-door (D2D) air travel is gaining momentum for airlines, airports, and feeder traffic providers. The mobility industry and researchers are broadening their scope to include the entire travel chain, from origin to final destination. Intermodal mobility products are already on the market. At the same time, widespread trends affect transport service providers (as the suppliers) and passengers (regarding demand). Acquiring a better understanding of future D2D air travel trends is crucial for the mobility sector for long-term planning, product adaptation, the services provided and the pricing of these, and improvements in the passenger experience. Focusing on the European market, the overall objective of this doctoral thesis is to identify and understand the future trends of D2D air travel. It is divided into three parts; these provide different perspectives on trends and employ a range of methods that lead to results that develop from each other.

In Part One, the Delphi technique is utilized to identify future travel trends. The study considers projections of European air passengers and their requirements for their entire air travel chain, including airport access, a long-haul flight, and airport egress. The research focuses on 2035 and is based on a two-round Delphi survey involving 38 experts from the transport industry, academia, and consultants. The Delphi survey is supplemented with findings from a preliminary study, consisting of a literature review, interviews with 18 experts in the field of air travel, and a workshop attended by experts. Results reveal that digitalization and personalization will be the main drivers in 2035 and that passengers might demand value-added use of their travel time. In addition, environmentally friendly travel products are considered desirable but only somewhat probable by 2035. Passenger type, age, origins, and travel budget will still be influential factors in 2035. Based on the results from a hierarchical cluster analysis, Part One presents three possible future scenarios: (1) personalized D2D travel, (2) integrated D2D travel, and (3) the game-changer. A technical chapter elaborates on the Delphi technique and individual research steps.

Part Two explores the supply aspect and to what extent transport service providers consider strategically relevant trends. The scope of D2D air travel is adapted by applying multi-labeled text classification models to 52 corporate reports from a sample of transport service providers that operate in the European market. Trends identified in the first Delphi study and from an additional literature review are used to develop seven classes. Two prototype models are developed: a dictionary-based classifier and a supervised learning model using the multinomial naive Bayes and linear support vector machine classifiers. The latter yields the best model output, revealing which trends have a higher, medium, or lower relevance on the supply side. The results show that providers consider environmentally friendly air transport and related products to be highly rele-

vant while disruption management, leveraging passengers' data, and improving airport feeder traffic through innovative mobility initiatives are considered to be of medium relevance.

Part Three explores air passengers' preferences and willingness to pay for ancillary services in the current transition into the *new normal*, brought about by the ongoing COVID-19 pandemic, high uncertainty, and changing market dynamics. A choice-based conjoint analysis is used to test six attributes within a hypothetical travel scenario for a long-haul one-way air trip. Choice data from 269 German business and leisure passengers are analyzed using a hierarchical Bayes estimator. Results reveal that the total ancillary service upgrade price influences passengers' choices the most, followed by a seat upgrade for greater comfort and the CO₂-compensation of a flight. Hygiene-related ancillaries bring low utilities. Female and senior passengers care more for environmentally friendly ancillaries. Confirming previous research, business passengers and frequent flyers care more for onboard comfort.

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Acronyms

ACBC	adaptive choice-based conjoint analysis
ACA	Airport Carbon Accreditation
ADP	Aéroports de Paris
AI	artificial intelligence
AR	augmented reality
ATM	air traffic management
AV	autonomous vehicle
B2B	business-to-business
CA	conjoint analysis
CAMERA	Coordination and Support Action for Mobility in Europe: Research and Assessment
CBC	choice-based conjoint analysis
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CSR	corporate social responsibility
CO₂	carbon dioxide
D	desirability
DCA	discrete choice analysis
DCE	discrete choice experiment
DCM	discrete choice modeling
CI	confidence interval
DB	Deutsche Bahn
DTM	document-term matrix
D2D	door-to-door
D2K	door-to-kerb
EU	European Union
FCM	fuzzy c-means
FF	frequent flyer
FRA	Frankfurt Airport
FSNC	Full-Service Network Carrier
GDP	Gross Domestic Product
GDPR	General Data Protection Regulations
G2G	gate-to-gate
G2K	gate-to-kerb

H	hypothesis
HC	hierarchical clustering
HB MNL	hierarchical Bayes multinomial logit
I	impact
IAG	International Airlines Group
IATA	International Air Transport Association
ICT	information and communications technologies
IQR	interquartile range
JFK	New York Airport
KKN	K-nearest neighbors
K2D	kerb-to-door
K2G	kerb-to-gate
LCC	Low Cost Carrier
LDA	latent Dirichlet allocation
LSA	latent Semantic allocation
MaaS	Mobility as a Service
MECE	mutually exclusive and collectively exhaustive
MICE	meetings, incentives, conferencing, and exhibitions
NB	multinomial naive Bayes
OAG	Official Airline Guide
OCR	online customer review
OEM	original equipment manufacturer
P	probability
PAM	partitioning around medoids
Q	question
RAF	renewable aviation fuels
RLH	root-likelihood
RMS	root mean square
RPK	Revenue Passenger Kilometers
RTD	Real-Time Delphi
RUT	theory of random utility
SD	standard deviation
SAF	sustainable aviation fuels
SOS	sampling of scenario
STEEP	social, technological, economic, environmental, and political
STM	structural topic model
SVM	support vector machine

TSP	transport service provider
UAM	Urban Air Mobility
US	United States
USP	unique selling proposition
VR	virtual reality
VFR	visiting friends and relatives
WTP	willingness to pay

Introduction

1.1 MOTIVATION

1.1.1 *Industry perspective*

To adapt products and services, build competitive advantage, and enhance operational processes, organizations try to constantly improve their decision- and strategy-making. This applies to the air transport system and its main players, such as airlines, airports, and other mobility providers (Schmitt and Gollnick 2016). A deep understanding of the macro and micro market environment is a foundation for strategic analysis, supported forecasts, and strategy developments (Conrady et al. 2019). Acquiring knowledge regarding future trends and possible scenarios supports these corporate activities.

However, air transport providers do not only focus on their transport segment; instead, they consider passengers' entire travel chain from their departure point to their final destination. From this door-to-door (D2D) air travel perspective, various pain points for passengers emerge, as well as the potential for improvement, regarding factors such as *long travel times* due to time-consuming feeder traffic and waiting time (Monmousseau et al. 2019, Rothfeld et al. 2019, Ureta et al. 2017), a lack of *comfort* (IATA 2019, Sezgen et al. 2019), and possible *travel disruptions* (Kim and Park 2016, Schulz et al. 2018, Sezgen et al. 2019), as well as aspects related to *planning, booking, ticketing and fares* (Baumgartner et al. 2016, Budd et al. 2016, Höser and Schmalz 2021). Unbundled and commission-based services that cover parts of the travel chain such as airport transfer, priority check-in, car rental, and hotel booking can further generate revenue for airlines, in addition to actual ticket sales (ancillary revenues) (Conrady et al. 2013, 2019).

This D2D air travel view is not new, and its benefits have been within the scope of the industry for a couple of years (IATA 2020c, Wade et al. 2020). Products and services combining travel segments are already on the market (Kluge et al. 2018b)¹, including Lufthansa's Rail&Fly service (Lufthansa 2019), D2D luggage delivery (Luggage Free 2020), and travel-planning platforms for intermodal travel that include the respective overall environmental impact (Eco-Passenger 2020).

To sum up, the D2D focus is highly relevant for the aviation industry² and seems beneficial when exploring future air travel trends.

¹Kluge is the maiden name, and the author is now called Schmalz.

²Although not in the main scope of this research endeavor, one needs to mention at this point that political agendas (European Commission 2011) and European Union (EU)-funded projects (CAMERA 2019, DATASET2050 2017) focus on D2D air travel making this topic also relevant for political institutes and policy making. This thesis, however, takes an industry perspective.

1.1.2 *Environment of change*

Airlines, airports, and providers of the airport feed, known as transport service providers (TSPs), face an environment of large-scale changes that affect the intermodal travel chain on various levels, including that of the passenger. The main trends are:

- **The COVID-19 induced crisis and the *new normal*:** Since the beginning of 2020, the COVID-19 pandemic has disrupted air travel. Before this, European inter- and intra-regional traffic (measured in Revenue Passenger Kilometers (RPK)³) was predicted to grow by 3.3% per year until 2037 (Airbus 2018). However, pre-COVID-19 recovery levels are estimated to be reached not earlier than 2024 (IATA 2021). To reach 2019 levels of demand, there is (among other factors) the need to regain passengers' trust in air travel. In light of the pandemic, D2D air travel may gain momentum. Combined offers can reduce points of contact, one of the main goals in times of social distancing, and help regain customers' confidence. Furthermore, travel safety must be redefined, especially regarding passengers' data, comfort, health, risk of contagion, and cross-border entry requirements.
- **Environmental and de-carbonization debate:** Aviation generates carbon dioxide (CO₂)- and non-CO₂-emissions (Lee et al. 2020). The threat of climate change and the increasing levels of concern within European society and politics has caused much debate as to how to tackle emissions long-term (European Commission 2019a,b). Examples of solutions include carbon-offsetting, innovative aircraft technologies, sustainable aviation fuels (SAF), and improvements in operations and air traffic management (ATM) (van der Sman et al. 2020). Meanwhile, environmental awareness and changes in behavior among the European population are increasing (European Commission 2019b, European Investment Fund 2020). Depending on the travel context, passengers rate the importance of flights differently, which provides room for reducing air travel (Gössling et al. 2019). The flight-shaming movement might further change people's willingness to fly towards more considerate air travel.
- **Digitalization and data:** Digitalization such as digital bookings, online check-ins, and combined ticketing already affects D2D air travel. Digital transformation is the key enabler for personalization, automation, and for the Mobility as a Service (MaaS) initiative (Kluge et al. 2018a)⁴. Providing digital travel services requires the use of personal data (Wade et al. 2020). Digitizing the travel chain and leveraging passengers' data may support the provision of integrated and digital D2D travel solutions (Höser and Schmalz 2021). Data analytics help to predict passengers' needs, enhance the travel experience, and improve operational processes from an economic and environmental perspective (Abduljabbar et al. 2019, Chung et al. 2020).
- **Diverse passenger profiles:** Different groups such as young (Garikapati et al. 2016) or elderly passengers (Siren and Haustein 2013, 2015) or tech-savvy

³Number of revenue passengers multiplied with total distance traveled.

⁴Kluge is the maiden name, and the author is now called Schmalz.

freelancers working in a gig-economy (Sinicki 2019) generate differentiated and fragmented customer needs (Kluge et al. 2018b). Diverse travel patterns of men and women might develop or increase (Scheiner and Holz-Rau 2017). The importance of social media in the travel context is increasing, mostly in terms of consuming travel information before a trip (Amaro et al. 2016). Due to the pandemic, consumer behavior and working patterns might change in the long term (McKinsey & Company 2020a). The last phenomenon might be known as *new work*.

- **New and advanced mobility concepts:** Advanced transport-related technologies, new mobility concepts, and innovative modes of travel affect passengers' consumption patterns (Bardhi and Eckhardt 2012, Young and Farber 2019). Enhanced mobility concepts for airport feed can decrease travel times and increase passengers' comfort, for example, with on-demand services and personalized offers but still make travel more sustainable and inclusive. Millennials are more likely to use alternative modes (Garikapati et al. 2016), like ride-hailing and car-sharing. Driverless cars allow the elderly to stay mobile (Siren and Haustein 2015). Advanced aircraft technologies might use hydrogen, renewable drop-in fuels, and electric propulsion, thus supporting airlines to use alternatives to kerosene to reach environmental goals (Bauen et al. 2020).
- **Infrastructure developments:** Innovative green transport modes require infrastructure changes, such as refueling and recharging stations, to be provided along the journey (European Commission 2020b). Passenger drones in the context of Urban Air Mobility (UAM) could be future airport feeders (Fu et al. 2019, Sun et al. 2018). One critical factor for its successful operations is the new vertiports for takeoff and landing (Vascik and Hansman 2017). The magnetic levitation and the hyperloop are also discussed as airport feeders connecting city centers and airports; however, they also require their own stations. Alternatives to kerosene, such as hydrogen, need different infrastructure at the airport and changes to an aircraft's design (Bauen et al. 2020).

1.1.3 Definition of door-to-door air travel and state of research

In this thesis, the D2D air-travel value chain includes an air travel segment and is concerned with passengers' entire journey from the starting point (the physical point where the journey begins) to the door at the destination (see Figure 4.1 for an illustration). Each travel segment is covered and considered. D2D air travel differs from urban D2D mobility as passengers might plan for more dwell time, carry luggage, and numerous TSPs are involved. Urban D2D mobility is not within the scope of this study, only partly as airport feeders. Packaged travel offered by travel companies, which may include feeder traffic services, as well as logistics, are also not considered.

Previous studies have examined questions related to D2D air travel or parts of it. Most work has explored passenger requirements (Chiambaretto et al. 2013, Kluge et al. 2018a, Lenoir and Laplace 2017, Urban et al. 2017) or travel time optimizations (García-Albertos et al. 2017, Monmousseau et al. 2019, Roth-

feld et al. 2019, Sun et al. 2018). Analyzing⁵ published work of 14 top-ranked transport-related journals⁶ of the last 15 years (Schmalz et al. 2021b), only 53 articles are related to D2D air travel, suggesting ample room for open research. The results show an increase in publications from 2015 onward, except for 2016, showing that this scope is gaining momentum in the scientific community (see Figure 1.1).

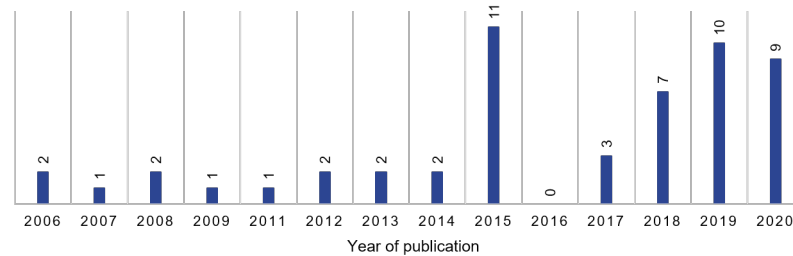


Figure 1.1: Scientific publications related to D2D air travel based on a keywords search (year 2006 - 2020).

1.2 OVERALL GOAL OF THIS DISSERTATION

1.2.1 Research questions

Based on the context of change, practical relevance of the topic, and a lack of research, the overall objective of this thesis is *to understand trends in the context of D2D air travel in the European market, incorporating both supply and demand issues*. In this context, supply refers to the main TSPs along the air travel chain such as airlines, airports, and feeders. The key trends mentioned above motivate an in-depth examination and discussion of D2D air travel supporting TSPs within strategy-, decision-, and product-making. Hence, this thesis takes an organizational view from the supply side. The demand side refers to the customer: the passenger. As, next to cargo, the transport system is created for passengers as main users, they need to be considered in the analysis. To break down the research goal, three main research questions (Qs) are investigated:

- (Q1): Trend identification - What could future D2D air travel look like?
- (Q2): Trend analysis regarding supply - To what extent do TSPs consider prevailing factors in their strategic planning and incorporate them into their communications?
- (Q3): Trend analysis regarding demand - What are passengers' preferences within the transition towards the *new normal*?

⁵Using the dictionary approach of this paper with keywords *door-to-door*, *door to door*, *door2door*, *D2D*, *intermodal*, *inter-modal*, *intermodalilty*, *integrated travel*, *travel chain* and *air travel*, *air transport*, *air journey*, *aviation*, *services*.

⁶*Journal of Travel Research*, *Journal of Air Transport Management*, *Transportation Science*, *Transportation Research Part A,B,C,D,E&F*, *Transportation*, *International Journal of Sustainable Transportation*, *Transport Reviews*, *Tourism Management*, *Travel Behaviour and Society*.

This research project is divided into three parts, following the research questions and providing different perspectives on future D2D air travel trends. Part One provides an expert view, whereas Part Two captures a high-level management view on the topic. Part Three provides an in-depth discussion of a trend in demand. All studies focus on the European or German market.

As depicted in Figure 1.2, the applied combination of approaches comprises a range of methods that will build upon the others' results and help to gain a deeper understanding of the overall objective. Combining different methods also allows a balance of limitations and different perspectives of the respective methods (Gerhold et al. 2015).

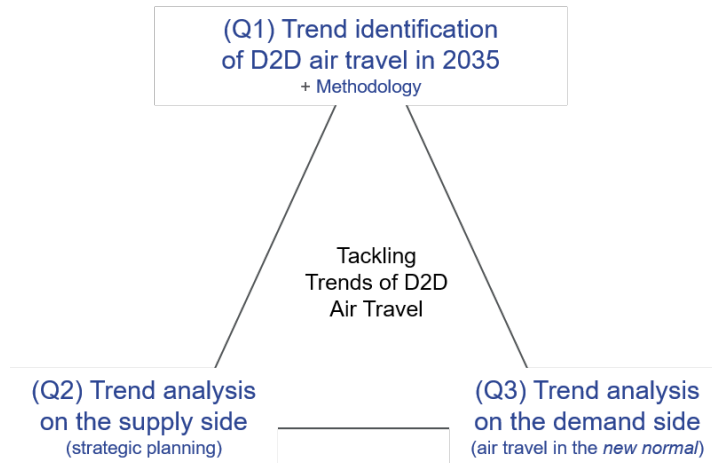


Figure 1.2: Approach of this dissertation project.

1.2.2 Structure of this dissertation

In Chapter 2, a Delphi-based scenario study is conducted to identify future D2D air travel trends on long-haul flights in 2035. Three scenarios that depict possible future trends for 2035 are developed. Chapter 3 explores the Delphi technique in depth and elaborates on each research step and lessons learned from a technical point of view. Chapter 4 examines if European TSPs (the supply side) already consider D2D air travel trends as relevant based on their corporate communication efforts. Two prototype models are developed: a dictionary-based classifier, and a supervised learning model. Chapter 5 presents a choice experiment to examine preferences of German passengers (the demand side) for ancillary services within the transition towards the *new normal* using a travel scenario on a long-haul flight. Chapter 6 concludes the findings of this thesis and derives overall managerial implications, limitations and potential for future research.

Door-to-door travel in 2035 - A Delphi study¹

2.1 INTRODUCTION

2.1.1 *Relevance of door-to-door air travel*

The airline industry is paying increasing attention to passengers' entire D2D travel experience rather than considering the flight segment only (Airliners.de 2018, Tritus 2018). Intermodal travel products for air passengers, such as Rail&Fly by Lufthansa and Deutsche Bahn (Lufthansa 2019) or the partnership between the application MyTaxi and Eurowings (Eurowings 2018), have already entered the market. In today's liberalized market, passengers can choose between numerous booking opportunities, airlines, airports, and ancillary products. Digitalization throughout the travel chain creates new opportunities, not only for transport companies but also for digital platforms that serve passengers. Platforms offering convenient, seamless booking experiences, e.g. Google, Airbnb, Uber, and Kayak (Javornik et al. 2018), increase competition. New infrastructure projects and emerging mobility concepts, providing feeder traffic options, such as ride-railing, can alter passengers' mobility patterns (Young and Farber 2019). Journey times to airports can influence passengers' choices, particularly regarding which airport to pick (Parrella 2013). Supplementary trends, like the current environmental debate and flight shaming, might also alter customers' D2D air travel. At the same time, airlines increasingly offer products tailored to differentiated customer needs, for instance a premium-economy cabin class on long-haul routes² (Kuo and Jou 2017).

To stay competitive and develop innovative, intermodal products, airlines and other travel companies should understand what travelers might want from integrated D2D mobility in the future, in addition to what successful D2D mobility offers could look like within this new paradigm. Enhanced knowledge may improve today's overall passenger satisfaction by reducing current travel *pain points*. Meeting or even exceeding passenger expectations creates customer satisfaction, which in turn leads to loyalty and positive word-of-mouth recommendations. These are important today, with user-generated online reviews that are accessible to everyone (Sezgen et al. 2019). Prospective customer desires can then be translated into passenger needs, cross-selling opportunities,

¹This chapter is based on Kluge et al. (2020): Kluge, U., Ringbeck, J., Spinler, S., 2020. Door-to-door travel in 2035 - a delphi study. *Technological Forecasting and Social Change* 157C, 120096. Please note that Kluge is the maiden name, and the author is now called Schmalz. Parts of this study were conducted within the CAMERA-project and many thanks go to the consortium. CAMERA (2019) has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 769606. The authors would also like to thank all experts who provided valued input within the interviews, in the workshop, during the pre-tests, and in both Delphi-rounds.

²Passengers are willing to pay additional US\$545 to enjoy this upgrade from the economy class on long-haul round-trips (Kuo and Jou, 2017).

and ultimately, new products or services (possibly realized through partnerships). However, despite its increasing importance, little research has been conducted to explore the future D2D travel market. Hence, the following research question emerges: *What could future D2D air travel look like?* This paper examines the relevant projections affecting future D2D air travel in Europe. It is here explored how the demand (passenger view) and supply side (transport market) of D2D air travel could develop and which scenarios could possibly occur.

2.1.2 *Delphi based scenario study*

There is high uncertainty around future developments. Only small amounts of information are available, and data collection is challenging, as consumers do not seem to be able to foresee what they desire for the future (Murugesan 2011). As the scope of this paper is on a future-oriented research question, the Delphi technique, among other research methods such as trend impact analysis, cross-impact analysis, qualitative trend analysis, or scenario methods, is selected as the most appropriate research method to explore the research question, by surveying experts instead of potential future customers (Döring & Bortz, 2016). The Delphi technique, which was first used in the 1950s, applied by the company RAND, is a multi-stage, anonymous, and written survey technique using experts to evaluate possible projections of what the future might look like (Linstone and Turoff 1975, 2011). The method has mostly been applied in health care, education, and business studies (Flostrand et al. 2020). Advantages of using the Delphi technique are manifold. Receiving valuations from across Western Europe, the method supports the process of bringing geographically dispersed experts together via one survey, and of letting them communicate easily with each other (Linstone and Turoff 1975). In that way, resources are conserved, and barriers against experts participating are kept low. The Delphi technique can also be combined with other methods. In this study, scenarios are developed that help to present the Delphi results in a vivid manner while supporting companies within their organizational learning and understanding of possible future developments (incl. shocks and uncertainties) (van der Heijden 1996).

As the transport sector starts to broaden its scope, beyond focusing only on one mode, taking the entire travel chain into consideration, the D2D focus is aimed here³. Airport access and egress modes are defined as feeder ground transports to and from the airport, such as bus services, airport shuttles, railway, taxi, or the personal vehicle. The scope of this study is the year 2035, within the European transport market for long-haul flights, taking into consideration the entire travel chain. The year 2035 is chosen as it seems to be a point in the future that will differ from today but is still imaginable for experts to assess in the survey. As projects in mobility and air travel have long-term planning horizons, this framework also offers providers the opportunity to imple-

³The focus is on D2D mobility only. Vacation packages provided by travel companies are not within this scope.

ment proposed managerial implications and to prepare products and services to cope with upcoming trends.

The long-haul air traffic market, defined here as flying over a longer distance and more than 4,000 km point-to-point⁴ (Crocker 2007, Eurocontrol 2005), has grown by 50% in the last ten years (Airbus 2018). In 2018, almost 10% of the total planned seat capacity was dedicated to long-haul⁵ routes (OAG 2018). Globalization and the growing (pre-COVID) demand for travel between regions might increase this further (ACI 2018, Airbus 2018). Emerging ultra-long-haul flights result in longer, non-stop flights increasing on-board journey time for passengers. Advanced aircraft technology, such as the A321LR planned for market entry in 2023 (Airbus 2019), will allow arrival and departure from smaller airports for long-haul routes. This could lead to changing passengers' travel behavior as traffic flow, along with access and egress modes, might be altered accordingly. Long-haul flights also generated more than 30% of the total fuel burn and related carbon dioxide (CO₂) emissions from global air transport in 2016 (BADA 2019), making travel of these distances of high interest in the light of the current environmental debate.

Providing the theoretical background in Section 2.2, key papers with a similar research scope are discussed. Section 2.3 presents an overview of the research process and the designs of the future projections; findings are used to develop the Delphi questionnaire. Section 2.3 also describes the two-round Delphi approach, including the expert selection and survey execution. Section 2.4 delineates study results and three future scenarios. Managerial implications are further discussed here. Section 2.5 concludes with limitations and future research.

2.2 PRIOR WORK

2.2.1 *Review of door-to-door travel research*

The understanding of D2D travel is mostly examined within the sphere of urban mobility. Stopka (2014) studies D2D travel with regard to public transport usage. Conducting focus group research, she identifies travelers' requirements for an application improving seamless D2D, urban mobility, as services on the current market cover only parts of the travel chain and do not support a seamless experience. Improving D2D trips is a complex endeavor, mostly due to incompatible systems and reluctance in sharing data (both provider and user). Similar challenges are also discussed in more recent works by Dolinayova et al. (2018) and Schulz et al. (2018), indicating little progress within the last years.

⁴The paper focuses on passengers using scheduled, commercial air transport services, based on the classification of civil aviation activities by ICAO (2009). According to this definition, commercial air transport services incorporate 1) scheduled and 2) nonscheduled air transport services. Nonscheduled air transport services include 1) charter; 2) on demand (air taxi, commercial business aviation, others); and 3) other nonscheduled air transport services. Business aviation, aviation training, pleasure flights and other activities are excluded here. The paper also does not distinguish between direct flights or connecting flights.

⁵Analysis of Official Airline Guide (OAG) data based on worldwide planned seat capacity; long-haul defined as flight distance > 4,000 km.

For instance, a first theoretical solution proposal for a privacy preserving architecture, supporting seamless D2D air travel, is developed by Höser and Schmalz (2021). In their work, privacy and secure data sharing are identified as open issues. Developing future passenger profiles, Kluge et al. (2018b) also analyze passenger requirements on D2D air travel chains and the respective mobility solutions. Results show that changes in demographics (like age) could still affect future passenger requirements. Travel time is an additional factor analyzed in the light of D2D travel, concerning the use of novel mobility concepts like on-demand air taxis (Sun et al. 2018) or regarding access and egress travel times (Rothfeld et al. 2019). Reducing the overall travel time seems to be a key driver in improving the passenger journey.

Overall, D2D travel needs to be improved in several ways. An understanding of possible future projections can help to create seamless, intermodal travel. For this exploration, future-oriented research is necessary.

2.2.2 *Delphi studies on the future of mobility*

Several Delphi studies examine the future of mobility (see Tabel 2.1 for an overview). They mostly focus on aviation and urban mobility, which are both sub-elements of D2D travel. A classical approach to a Delphi-based scenario study is applied by Linz (2012) focusing on the question of what aviation of the future might look like in 2025, with respect to passenger, business, and cargo aviation. Linz does test projections describing developments concerning social, technological, economic, and political aspects (STEP-framework), with aviation industry experts and researchers. Based on the study's outcomes and a cluster analysis, Linz develops three future scenarios for the aviation industry overall: (1) the probable scenario with the highest probability to occur, (2) eventualities, and (3) potential surprises, characterized by the lowest estimated probability. As Linz's industry focus is broad, it seems difficult to summarize each scenario. However, Delphi findings confirm within one projection that "[c]ustomers will increasingly demand integrated services, door-to-door, out of one hand (one-stop-shopping)" (Linz 2012, p.3), underpinning the D2D scope as a relevant future paradigm.

Applying the Real-Time Delphi (RTD)⁶ approach, Wittmer and Linden (2017) validate future projections for two mobility scenarios for the Swiss transport market in 2040. Delphi results show that future customer needs of Swiss passengers will be diverse and complex. Individual lives and future working environments are two confirmed aspects that could change and influence passengers' mobility behavior in Switzerland. Wittmer and Linden do not distinguish between daily commuters or air travelers. Several key findings are also tested further in this study for D2D air travel.

A local focus to the research is applied by Julsrud and Uteng (2015) as well as by Spickermann et al. (2014a). Future projections for day-to-day mobility within urban areas in Norway for the year 2050 are developed by Julsrud and Uteng. Evaluated by national experts from academia and the mobility industry in a RTD survey, the authors develop three possible visions of future urban

⁶Web-based.

mobility in Norway: (1) technopolis, (2) controlled mobility, and (3) shared mobility. Within a multi-stakeholder scenario development study, Spickermann et al. design a desirable future vision and probable perspectives for future urban mobility in Germany. Three parallel online Delphi surveys are carried out to capture a broad view from multiple expert groups. The study reveals that multimodal mobility in urban areas might increase, and, at the same time, customer expectations and urban transport systems are also likely to change before 2030.

Mason and Alamdari (2007) conduct a two-round Delphi study determining future developments of network carriers, Low Cost Carriers (LCCs), and passengers projections within the EU air transport market. Outcomes reveal possible route network developments, market consolidation trends, and changes in passenger demand. Mason and Alamdari use a shorter time horizon and focus on the year 2015, which has only been eight years away at the time of the study.

The Delphi technique is also applied in studies with a broader scope of transport and mobility research, such as by Linz et al. (2011) examining the European business aviation industry. One could also apply the scenario approach (Michelmann et al. 2019, Will et al. 2016), which can also be combined with the Delphi technique. An overview of transport related Delphi studies with a focus on scenario development is provided by Melander et al. (2018).

Looking at the prevailing literature, the Delphi technique is suitable for examining future-oriented, mobility-related research questions. Gaining different perspectives and avoiding biases, researchers seem to prefer diverse sets of experts, often combining panelists from both the industry and academia. The most common approaches are RTD or two-round Delphi studies with an overall response rate of 51% across all studies. As also discussed by Nowack et al. (2011), the number of panelists seems higher in the RTD. The RT approach could help to reach a higher number of participants; however, the quality of a Delphi study also depends on the qualifications of the experts. Using the offline Delphi approach, we can potentially reach more pertinent domain experts.

2.2.3 *Contribution to the literature*

Intermodal D2D travel is gaining momentum for transport companies and researchers, mostly studying D2D urban mobility. This paper examines the relevant future projections affecting D2D air travel in Europe. To the knowledge of the authors, this scope has not been used in any Delphi survey yet. The long-haul market is identified as an important air transport product. Compared to prior Delphi studies, this research also focuses on air passengers taking long-haul flights. The Delphi technique helps combine experts' judgments from several transport providers, thus creating a D2D scope. Further, the research objective is not just to gain consensus among the experts but also to analyze which projections trigger diverse opinions. The theoretical contribution of this research to the literature on future mobility and for the industry is threefold. The findings contribute to (1) the current Delphi literature (and future-oriented research community) by applying a novel scope of D2D air travel; (2) exemplifying that the Delphi technique is a sufficient tool for capturing this broad

Table 2.1: Delphi studies within mobility and transportation research.

Author (s) (Year)	Study Scope	Time Horizon	# of Projections	# of Panelists	# of Rounds	Response Rate	Research Details
Julsrud and Uteng (2015)	Urban, daily mobility in Norway	2050	16	280	RTD ^a	56%	Delphi combined with factor analysis
Wittmer and Linden (2017)	Overall mobility & passenger traveling in Switzerland	2040	19	50	2 (RTD)	64%	Delphi survey combined with consumer survey, workshops, expert-interviews, means-end analysis and customer segmentation
Schuckmann et al. (2012)	Transport infrastructure	2030	15	104	RTD	31%	Delphi study
Spickermann et al. (2014a)	Urban mobility in Germany	2030	16	201	RTD	28%	Three parallel Delphi studies with different expert groups, combined with workshops and scenario development
von der Gracht and Darkow (2010)	Worldwide, logistics service industry	2025	41	30	2	42%	Extensive Delphi-based scenario study
Linz (2012)	Aviation industry (incl. cargo)	2025	40	57	RTD	71%	Delphi-based scenario development
Linz et al. (2011)	European business aviation industry	2025	25	57	Ø _{3,1} (RTD)	71%	Real-time Delphi survey combined with STEP-framework, Porter five forces and expert interviews
Mason and (2007)	Air transport in the EU	2015	27 (round 1) 14 (round 2)	26	2	43%	Two-round Delphi; projections developed based on desk research and by air transport researchers

^aRTD: Real-Time Delphi (web-based)

scope, by surveying multi-stakeholder panelists; (3) the transport industry, by providing insights into possible future projections and elaborating on managerial implications.

2.3 DELPHI SURVEY

2.3.1 Future projections

This Delphi study followed a four-step research approach (Figure 2.1). This section elaborates on the development of future projections (step one). To ensure data triangulation and to identify main focal points to discuss in the Delphi survey, the use of multiple sources for the development process is recommended (Belton et al. 2019, Nowack et al. 2011). Hence, three sources were used here: (1) semi-structured expert interviews, (2) one exploratory expert workshop, and (3) a literature review providing theoretical background.

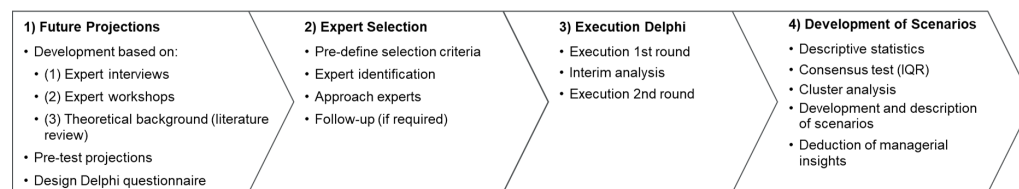


Figure 2.1: Design of this Delphi study, depicted as four-step research approach (adapted from von der Gracht and Darkow (2010)).

2.3.1.1 Expert interviews and expert workshop

Expert interviews were used for this study in an exploratory way (Bogner et al. 2014). They helped to gain an understanding of how European D2D mobility could look in 2035, by incorporating the industry at an early stage of the research process and identifying essential D2D travel trends to use as focal points for the projections. Of the 55 experts who were contacted, 18⁷ agreed to be interviewed. Interviews were carried out via phone or face-to-face from March until October 2018. In line with the D2D scope, interviewees covered all segments of the travel chain. Representatives from public transport providers and car manufacturers covered airport access and egress modes (feeder traffic). Two airports and two airlines covered the airport transfer and the flight segment. Additionally, representatives of business-to-business (B2B) suppliers from the aviation and automotive industry, a mobility researcher, and five mobility experts on digitalization and marketing methods were included for a third perspective. All interviews were semi-structured, using the interview questionnaire as a guidance for the conversations (Döring and Bortz 2016). The regional focus was on the European travel market. After obtaining consent from experts, interviews were recorded and transcribed based on Kuckartz (2014), who provides transcription rules focusing on content. The coding of the qualitative interview data was based on the summarizing and inductive

⁷The overall response rate is 33%. 17 expert interviews have been conducted within the CAMERA-project, funded under H2020 “Aviation Research and Innovation Policy,” GA769606.

category formation approach proposed by Mayring (2014). Based on findings of the expert interviews and the accompanying literature review, a first list of 51 projections was drafted. A further exploratory workshop, with two mobility researchers, was carried out in October 2018, revising all projections, suggesting additional projections, broadening the perspective, and breaking down the list to develop the questionnaire draft.

2.3.1.2 *Expert interviews and expert workshop*

As recommended by the literature (Belton et al. 2019, Frewer et al. 2011), to refine the questionnaire and to ensure plausibility, comprehensibility, and consistency, the draft questionnaire was pre-tested with two adequate experts, who were not part of the expert panel. Based on their feedback, minor modifications were carried out. Avoiding research fatigue and keeping the dropout rate low, the final list was shortened to 17 projections (Table 2.2). The final list is not exclusive nor exhaustive but covers essential future D2D mobility trends as identified. Projections are structured further to evaluate external factors impacting future D2D mobility. Adapted from Linz (2012), the social, technological, economic, environmental, and political (STEEP) development framework was used for an additional grouping. Most projections are assigned to the social and technological category, indicating these two as possible drivers for future D2D mobility.

Throughout the Delphi study, an annual Gross Domestic Product (GDP) growth of 1.8% and a stable population (no strong growth or decrease) were expected. An annual RPK growth at 3.1% were assumed as a proxy for air travel demand for the European market until 2035 (adapted from Airbus (2018) and United Nations (2017)). No financial crises, natural catastrophes, medical crises, nor terrorist attacks were assumed either. This scenario was added to the questionnaire so that experts could presume them to be framework conditions when completing it. Following, it is presented how interview data, findings from the literature review, and workshop insights were used to design the final projections.

2.3.1.3 *Theoretical background: trends on the demand and supply side*

As argued by the interviewed experts, one major trend is the personalized journey, which provides a high customer benefit. Driven by the passenger, the transport market is considered to be transformed from offered mobility to demanded mobility. Customers want on-demand, flexible solutions, adaptable towards personal preferences. This trend is essential within the D2D context, as travel chains are individualized to a high degree depending on passenger type, itineraries, and available budget. The connected, personalized passenger journey is also discussed in the recent technical press (Schaal 2019, Sheivachman 2019). The increasing demand for personalized D2D journeys is hence further tested in the Delphi study (projection 1).

Several studies look into demographic trends in the context of travel. Millennials (young adults) are characterized by Garikapati et al. (2016) as a generation owning less cars, traveling less, and spending more time at home. Their mobil-

Table 2.2: Final projections of future European D2D air travel into the year 2035 and sources of development.

No.	Projections (year 2035)	Category (STEEP)	Demand / Supply Side	Source
1	In 2035, passengers will increasingly demand personalized D2D journeys (on- Social demand, flexible & adapted towards personal preferences).	Social	Demand	Expert interviews, Schaal (2019), Sheivachman (2019)
2	In 2035, age will not define passengers' needs that much anymore.	Social	Demand	Expert interviews, Ganikapati et al. (2016), Siren and Hausteijn (2013, 2015), Wittmer and Linden (2017)
3	In 2035, gendered travel preferences within D2D journeys will increasingly differ from each other.	Social	Demand	Expert interviews, Scheiner and Holz-Rau (2017), Siren and Hausteijn (2013, 2015)
4	In 2035, novel working environments will influence requirements of business travelers on the D2D travel chain.	Social	Demand	Expert interviews, Sinicki (2019), Wittmer and Linden (2017)
5	In 2035, passengers will increasingly demand to use travel time along their D2D journey as value-adding time (such as for working, networking, education, etc.).	Social	Demand	Expert interviews, Bouwens et al. (2017), Tang et al. (2018)
6	In 2035, passengers will increasingly demand not just transportation services but comfort and convenience along their D2D journey (such as options for sleeping and napping, comfortable seating, etc.).	Social	Demand	Expert workshop, Bouwens et al. (2017), Vink & Hiemstra-van Mastrigt (2011)
7	In 2035, passengers will be increasingly price sensitive throughout the entire travel chain.	Economic	Demand	Expert interviews, Conrady et al. (2013)
8	In 2035, passengers will increasingly be willing to pay more for eco-friendly D2D journeys.	Environmental	Demand	Expert interviews, Alcock et al. (2017), Büchs (2017), Lu & Wang (2018)
9	In 2035, passengers will increasingly provide private data to personalize their D2D journeys.	Technological	Demand	Expert interviews, Dolinayova et al., (2018); Javornik et al., (2018); Schulz et al., (2018)
10	In 2035, internet-enabled mobility services will be the personal travel planner of passengers and completely control each aspect of their D2D journeys.	Technological	Demand	Expert interviews, Linton & Kwortnik (2019)
11	In the context of increased automatization and digitalization in 2035, passengers will increasingly demand human interaction throughout their D2D travel chain.	Technological	Demand	Expert interviews
12	In 2035, advanced information and communications technology (ICT) will partly replace long-haul air travel for private trips (such as holidays, visiting friends and relatives, etc.).	Technological	Supply	Expert workshop, Voronkova (2018)
13	In 2035, autonomous mobility will facilitate D2D mobility.	Technological	Supply	Expert interviews, Expert workshop, Young & Farber (2019)
14	In 2035, providers along a D2D travel chain, such as public transport, airports, airlines, and travel platforms, will increasingly collaborate to offer integrated mobility products and services.	Economic	Supply	Expert interviews, Javornik et al. (2018)
15	In 2035, integrated offers around D2D mobility will become the competitive advantage for airlines.	Economic	Supply	Expert interviews, Javornik et al. (2018)
16	In 2035, airlines, public transport, and airports will mainly focus on providing transport services. Tech companies will take over additional services offered to passengers (such as on-board shopping, entertainment, etc.).	Economic	Supply	Expert interviews, Chang (2017)
17	In 2035, political frameworks will support integrated, seamless D2D mobility.	Political	Supply	Expert workshop

ity behavior might change with age (early 30s) given a new life stage. At that point, Millennials are likely to adapt a similar mobility behavior as the prior generation. Due to factors such as increased longevity and lifestyle changes, Siren and Haustein (2013, 2015) show that the generation of Baby Boomers, entering retirement age, will be in turn very active in travel and leisure activities. Elderly passengers (50+) do not comprise a homogeneous segment but different sub-segments that behave increasingly atypically to their traditional patterns, described as down-aging by Wittmer and Linden (2017). Several interviewed experts predicted the retention of traditional segments with fragmented changes in the mobility behavior and lifestyle. Age might not be a differentiating characteristic for passengers' mobility needs; this trend is tested for D2D long-haul travel (projection 2).

Besides age, recent research shows gendered differences within mobility behavior. Scheiner and Holz-Rau (2017) show that women's daily travel patterns are more complex compared to those of men. Women tend to conduct more trip chaining due to the increased number of tasks, with females still carrying out more family duties and having additional anchor points. Female travel behavior also differs in the older age cohort of the population (Siren and Haustein 2013, 2015). Findings from expert interviews predict a further growth in female business travelers. Women have differentiated travel needs along the travel chain (focusing more on healthy offers and safety), but air travel with its surrounding infrastructure (physically and service-wise) is still male-oriented, leading to possible future pain points for the increasing number of female business passengers. It is hence explored if gendered preference might develop in the future (projection 3).

As a side finding, future passenger segments were identified during the expert interviews. One of these was the business traveler segment, which already exists today. Wittmer and Linden (2017) identified, in a former Delphi study, that new working environments might possibly influence the mobility behavior of the Swiss market in 2040. The new era of the gig economy (defined as an employment system with many temporary, short-term contracts, often applicable to tech professionals (Sinicki 2019)) is considered by the experts to be a high growth market. Self-employed experts and freelancers are mobile, and hence, travel increasingly for temporary, short-term project work and engagements. Some of these gig workers might not have places of permanent residence, creating new customer needs along the journey, such as mobile offices, luggage storage, showers, or medical care. It is tested if such novel working environments could influence requirements of business travelers (projection 4).

Time is already identified as a main driver in the current D2D travel literature, mostly with respect to time saving. Interviewed experts however elaborated on the requirement of passengers to spend actual travel time in a value-adding way, such as for working or entertainment, instead of losing time while traveling. As seen in examples for high-speed rail and long-haul flights, this can vary as preferences for on-board activities are diverse (Bouwens et al. 2017, Tang et al. 2018). For long-haul D2D travel, creating value-adding time is essential for the actual long flight but challenging for all transport modes along the journey. Hence, this possible challenge is also tested in the Delphi study (projection 5).

Moreover, the personal comfort levels during different activities and flight phases of long-haul flights varies (Bouwens et al. 2017, Vink and Hiemstra-van Mastrigt 2011). Legroom, seats, hygiene, and crew behavior are influential comfort factors in an aircraft cabin (Vink and Hiemstra-van Mastrigt 2011). Next to the actual transport service of providers, researchers from the expert workshop discussed the hypothesis, whether this would become a demand covering the entire travel chain in 2035. Hence, comfort as a demand driver is tested in the Delphi study (projection 6).

Besides, the price sensitivity of airline passengers is currently high (Conrady et al. 2013), and the majority of interviewed experts argued that this could be an upcoming challenge for the transport industry. Mobility is already a commodity and providers need to offer an entire travel experience to differentiate their products on the market. Next to ticket fares, parking charges at airports can also be extremely high, as parking time increases when traveling long-haul. With regard to access and egress modes, emerging mobility platforms and sharing modes offer feeder traffic at low costs, competing with public transport fares. This increasing price sensitivity is verified in this Delphi study (projection 7).

Another aspect is the mitigation of self-generated emissions by passengers, particularly applicable to the scope of this study as long-haul air traffic has generated more than 30% of the total fuel burn, and subsequent CO₂ emissions, of global air transport (BADA 2019). Passengers' mitigation strategies could be paying for voluntary carbon offsetting schemes (Lu and Wang 2018), or reducing the personal propensity to fly (Büchs 2017). Studies show that passengers continue to fly despite concerns about their known personal impact on climate change (Alcock et al. 2017); this is known as the value-action gap (Büchs 2017). As the environmental aspect was also seen as a major challenge for the overall transport system by interviewed experts, and is currently highly debated by society at large in many parts of the world, the increasing willingness of passengers to pay more for environmentally friendly travel is tested in the Delphi study (projection 8).

To provide tailored mobility solutions and to create a personalized journey experience, transport providers have already started to use the passenger data available to them, gathered from the booking process and loyalty programs, traffic data, and in-house survey results. Secondary data, from other mobility companies, competitors, or market research companies, is also accessed. To offer a true personalized journey, providers need all D2D information from the passenger side (Javornik et al. 2018), but the willingness to share data between providers is still low (Dolinayova et al. 2018, Schulz et al. 2018). Interviewed experts also considered data security regulations, increased competition, lack of in-house data analytic skills, and customer data security concerns as possible drawbacks. It is hence to be tested, if future passengers would be willing to provide data for personalization (projection 9).

Interviewed experts foresaw personal mobile devices or travel platforms to become interim media for travel planning and managing, schedules knowledge, and other D2D information, to provide seamless mobility solutions. Such 'travel buddies' will also adopt to individual preferences and possible disruptions during the journey, translating between the demand and supply sides. It

could also be considered as a solution for regulating societal interests, such as avoiding overcrowded stations and intersections or for choosing environmentally friendly routes. There is still a supplier–user gap, partly as it is challenging to keep information on mobile devices up to date (Linton and Kwortnik 2019). It is tested if internet-enabled mobile services could become personal D2D travel planners (projection 10).

In times, with automatization and digitalization as driving trends in the travel industry, processes and touch points along the travel chain will increasingly be replaced by machines. However, interviewed experts argued that human contact would still play a vital role for passengers in the future, especially for customers who experience a high amount of stress at the airport, such as children traveling alone or sporadic flyers. Human touch could become a main differentiator for transport providers and is hence investigated for future D2D air travel (projection 11).

Conversely, during the conducted expert workshop, concerns arose that advanced information and communications technologies (ICT), such as augmented reality (AR) and virtual reality (VR), could partly replace long-haul air travel for holidays or visiting friends and relatives. VR-glasses replacing tourism has several advantages, such as virtual tours to museums and difficult to reach cultural heritage sites or offering remote tourism to the disabled and the elderly (Voronkova 2018). Yet it seems uncertain how ICT and virtual tourism might replace air travel for private purposes and hence it is tested (projection 12).

Emerging mobility concepts, such as ride-railing, can alter passengers' travel desires and mobility patterns (Young and Farber 2019). Advanced technology, such as autonomous vehicles (AVs), might further facilitate D2D mobility and offer innovative modes for access and egress. Experts stated that either existing modes could be used differently (like cars) or new forms of mobility could emerge (such as UAM). Such modes of the future, primarily with focus on AVs providing airport access and egress, are seen as value-adding facilitators for travel time use within the travel chain. Further customer benefits are the availability of AVs at any time and the low costs. The effect of those on D2D is tested in the Delphi study (projection 13).

The digital transformation allows airlines and ground transport to work better together within a connected ecosystem (Javornik et al. 2018). In fact, partnerships between providers were seen as necessary for providing a true D2D experience (see projection 9) but also as challenging by the interviewed experts. Some D2D mobility products, based on partnerships, already exist. It is tested if providers increasingly collaborate to increase D2D services (projection 14).

Interviewed experts also argued that such integrated offers around D2D mobility could become a competitive advantage for airlines. As discussed in the literature, airlines should start to change their management mind-set towards creating true value for their passengers (Javornik et al. 2018). Mobility is already a commodity and providers need to offer an entire travel experience to differentiate their services. This hypothesis is also assessed by the Delphi panel (projection 15).

This trend could also develop differently. In 2035, airlines, public transport, and airports could mainly focus on providing the pure transport services of D2D. Tech companies could take over additional services offered to pas-

sengers, such as on-demand, on-board entertainment by the movie streaming provider Netflix, who has already partnered up with airlines (Chang 2017), as they already have passengers' data and know the customers' preferences. This counter-trend proposed by the interviewed experts is tested in the Delphi (projection 16).

Autonomous driving (see projection 7) is seen by experts to be market-ready in ten to fifteen years. The technology already exists, but official regulations in terms of usage and safety are not currently in place. Mobility platforms and emerging sharing modes covering access and egress might require further regulations. As discussed in the expert workshop, political frameworks could be an enabler of enhanced D2D mobility. The Delphi tests if political frameworks could support D2D mobility (projection 17).

2.3.2 *Expert selection*

The identification of experts was based on two sources, desk research (LinkedIn and conference participation lists) and the personal networks of the authors. As shown in Section 2.2, it seems beneficial to include multi-level perspectives in the expert panel to avoid biases. To ensure such heterogeneity, approached experts had to have an academic background, represent a transport company, work as futurists, or work in mobility consultancy. To capture a true D2D focus as was done in the expert interviews, the selected experts represented a diverse set of means of transport, such as public transport, air (airports and airlines), automotive, and their suppliers. Another pre-selection criterion was the European scope, panelists should mainly have been based and/or worked in Europe. Experts should also have profound mobility expertise, assured via their curriculum vitae.

A total of 45 experts participated in the first survey round of the 113 experts contacted via e-mail, phone, or in person. Due to too many missing answers, two questionnaires were eliminated, leading to a total of 43 participants in round one (response rate 38%). Of those, 504 comments out of 731 possible comments were provided (comment rate 69%). Such high comment rate could be an indicator of a high level of involvement from the experts. In the second round, 5 experts dropped out (dropout rate 12%), leading to 38 final participants and to an overall response rate of 34%. The experts had, on average, 14 years of experience within the mobility sector, ranging from 3 years to over 40 years. 31 participants rated their own expertise for answering the questions as 'high' or 'very high', six assessed their expertise as 'basic' and one as 'low'⁸. 39% of the panelists were female. The divisions of panelists by industry segment and job level are depicted in Table 2.3.

⁸Due to the careful usage of prior expert selection criteria, the low self-assessment response of one participant could be explained through a higher degree of critical self-assessment of one's own competence and expertise.

Table 2.3: Delphi participants by industry segment (due to rounding >100%) and job level.

Industry / mode (most applicable)	N (in %)	Position	N (in %)
Research facility or university	16 (42%)	Researcher (PhD / Dr.)	8 (21%)
Public transport	5 (13%)	Employee	7 (18%)
Supplier	4 (11%)	Middle Management	5 (13%)
Airport	3 (8%)	Researcher (Prof.)	4 (11%)
Consulting	3 (8%)	Top Management	3 (8%)
Automotive	3 (8%)	Researcher (Doctoral Student)	3 (8%)
Other	2 (5%)	Consultant	3 (8%)
Airline	1 (3%)	Futurist	3 (8%)
Futurist	1 (3%)	Other	2 (5%)

2.3.3 Execution of the Delphi study

Various Delphi techniques have evolved next to the traditional approach, as published by Linstone and Turoff (Linstone and Turoff 1975, Rowe and Wright 2011). For the purpose of this study, a two-round Delphi technique was applied. As the overall research goal was not to gain consensus among all experts, the Delphi was pre-limited to two rounds. Three rounds or more were not considered able to increase the quality of the findings but could have increased the risks of research fatigue and panelist dropout. Hence, rounds were capped to avoid a high panel motility.

The final Delphi questionnaire for the first round was created as a read-only word form and distributed to experts via e-mail, along with a covering letter containing information concerning the scope of the study, an overview of the research approach, and information to preserve anonymity and confidentiality. The first part provided a future scenario, as described above, as well as instructions for the answering process. In the main part, experts were asked to evaluate the expected probability (P), impact (I), and desirability (D) for each projection on a seven-point Likert scale, providing sufficient variance for the experts' answers. Depending on the estimation, the value 1 was defined as 'not probable', 'very weak', or 'very undesirable'. Respectively, the value 7 was defined as 'very probable', 'very strong', and 'very desirable'. As seen in other transport-related Delphi studies such as Schuckmann et al. (2012), providing a written justification in support of the personal assessment was optional. In the second part of the questionnaire, basic socio-demographic information was requested, such as gender, position, type of company, years of experience in the mobility industry, and a self-assessment of the experts' expertise measured on a five-point Likert scale, going from 'very low' (1) to 'very high' (5).

To guarantee anonymity and an unobstructed process, the entire Delphi process was coordinated by a moderator who was not part of the panel. The first round was conducted between October 2018 and November 2018 and the second round between December 2018 and January 2019. In order to gain as many participants as possible, at least one e-mail reminder was sent to the contacts for each round.

2.3.4 *Interim analysis*

Based on guidelines by Häder (2009), participants received controlled feedback in the second round. The spread of the aggregated results in format of histograms, the means, the minima and maxima of all answers, a summary of all comments regarding each projection as well as the position of one's own response compared to overall results, were provided. In line with the approach of the Delphi technique, experts had the possibility of revising their estimations, based on the additional information provided. Participants were also invited to leave a comment in case they wanted to adapt answers. Although the dropout rate between the two rounds was unexpectedly high, experts provided estimations for all projections in the second round, leading to a dataset without any missing values. This can be seen as an indicator of a high panelist engagement level.

2.4 DEVELOPMENT OF SCENARIOS

2.4.1 *Descriptive statistics*

Before analysis, the data from both rounds was checked for errors (Häder 2009). Descriptive statistics, such as the calculations of the means, medians, and standard deviations (SDs), were generated. The interquartile range (IQR) was used as the measurement of consensus. The change in the standard deviation between rounds was used as a measurement of convergence. An extract of the results is depicted in Table 2.4, including the short title of respective projections.

As all estimations were measured on the seven-point Likert scale, a standardization of the data was not necessary. After round two, a decrease in the standard deviation (measured in the % SD change) of the probability was observed for eleven projections, indicating a convergence of estimations among the experts. Comments of participants on the rationales behind why they altered their estimations in the second round supported this. The strongest convergences between the rounds were measured for projection 9 (private data) with a decrease in SD of 13.16%, projection 11 (automatization and digitalization) with a decrease in SD of 10.49%, and for projection 4 (novel working environments) with a decrease in SD of 7.23%.

Most projections were considered to have an average impact greater than or equal to 5, which is equivalent to 'somewhat strong' or stronger, indicating that relevant projections were addressed in the Delphi. The strongest impact was estimated for projection 9 (private data) with a mean of 6.13 and for projection 14 (collaborate mobility providers) with a mean of 6.13. Projection 14 (collaborate mobility providers) was also considered as the most desirable development for D2D journeys in 2035 ($D = 6.18$). Although projection 8 (eco-friendly journeys) was estimated as only 'somewhat probable' ($P = 4.76$), it was the second most desirable development according to the experts ($D = 6.03$).

Plotting the mean of probability versus the mean of impact revealed an almost linear development within the data (Figure 2.2). Each number in the

Table 2.4: Quantitative results (extract).

Projection (short title)	P round 1 (N = 43)				P round 2 (N = 38)				SD change (in %)	I (mean)	D (mean)
	IQR ^a	Median	Mean	SD ^b	IQR	Median	Mean	SD			
1. Personalized D2D journeys	1	6	6.19	1.03	1	6	6.18	1.06	2.91	5.84	5.58
2. Age	3	3	3.3	1.61	3	3	3.32	1.54	-4.35	4.53	4.32
3. Gender	4	3	2.98	1.71	2.75	3	2.87	1.61	-5.85	3.53	3.53
4. Novel working environments	1	6	6.02	0.83	0.75	6	6	0.77	-7.23	5.66	5.37
5. Value-adding time	1	7	6.44	0.85	1	7	6.45	0.83	-2.35	6.03	5.76
6. Comfort & convenience	2	6	5.79	1.26	1	6	5.87	1.28	1.59	5.66	5.61
7. Price	2	5	5	1.18	2	5	5.13	1.19	0.85	5.03	4.26
8. Eco-friendly journeys	2	5	4.72	1.37	1.5	5	4.76	1.34	-2.19	5.08	6.03
9. Private data	2	6	5.98	1.14	2	6	6	0.99	-13.16	6.13	4.82
10. Internet-enabled mobility services	1	6	6.14	1.1	1	6	6.11	1.16	5.45	6.08	5.29
11. Automatization & digitalization	2.75	4	3.69	1.62	2	4	3.74	1.45	-10.49	4.63	4.21
12. ICT	3	3	3.33	1.68	3	3	3.37	1.65	-1.79	4.24	3.71
13. Autonomous mobility	2	6	5.95	1.09	2	6	5.95	1.14	4.59	6.08	5.79
14. Collaborate mobility providers	1	7	6.14	1.18	1	7	6.13	1.23	4.24	6.13	6.18
15. Competitive advantage	2	5	4.93	1.5	2	5	4.66	1.44	-4.00	5.08	4.87
16. Tech companies	1.75	5	4.6	1.53	1	5	4.53	1.45	-5.23	5.11	4.18
17. Political frameworks	2	5	5.1	1.22	1.75	5	5.08	1.17	-4.10	5.53	5.74

^aIQR: interquartile range (Q₃ – Q₁)^bSD: standard deviation (in %)

scatter plot indicates the corresponding projection. Projections with a lower mean of probability went along with a rather weak impact and vice versa. For instance, projection 3 (gender) was estimated to have the lowest probability to occur in 2035 and would also have the lowest impact. As also seen in Table 2.4, projections that reached consensus showed higher impact and probability estimations, indicated in Figure 2.2 by the dashed line.

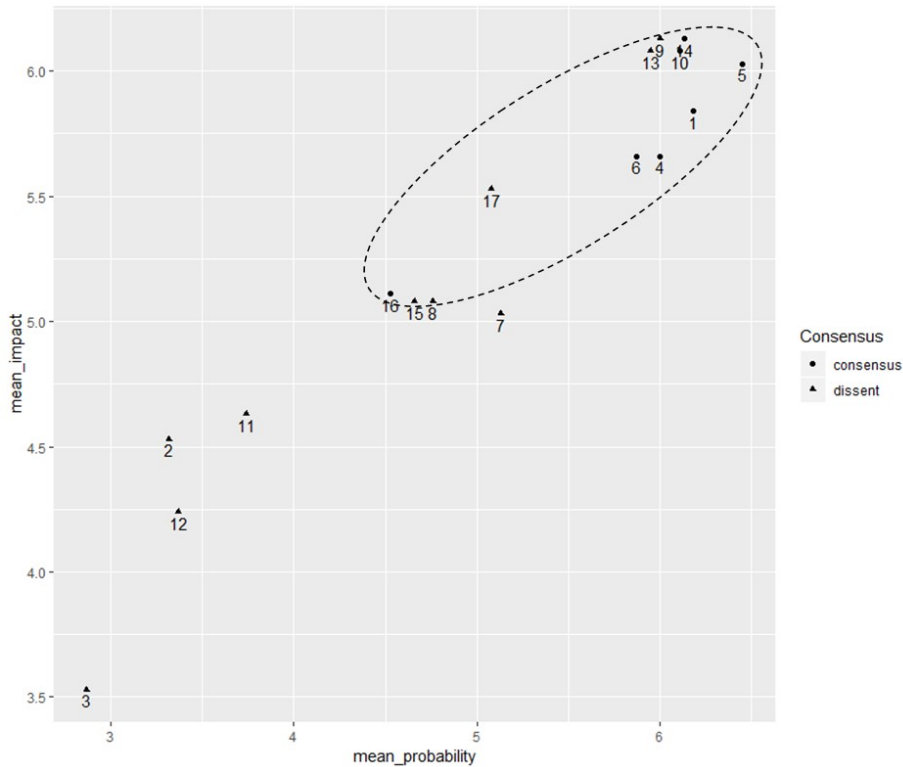


Figure 2.2: Scatter plot (all 17 projections).

The measurement of consensus is a key component in analyzing Delphi results, and the IQR is a widely accepted and largely used classification for this purpose (von der Gracht 2012). A small IQR indicates a large consensus among the panelists. As seen within other Delphi studies using a seven-point Likert scale (Vet et al. 2005), the IQR threshold for reached consensus of ≤ 1 was used. Projections with higher IQR values were not considered in scenario development. In round one, consensus was obtained for projection 1 (personalized D2D journeys), projection 4 (novel working environments), projection 5 (value-adding time), projection 10 (internet-enabled mobility services), and projection 14 (collaborate mobility providers). Although the panel was rather diverse, consensus was obtained for two additional projections (6 and 16), after the second round. All projections reaching the threshold were related to changing passenger needs, novel business models, and technology; many were driven by digitalization, such as internet-enabled D2D mobility services, or new service offers by tech companies. Additional descriptive statistics were conducted with these seven projections, including checking for correlations and developing boxplots to depict outliers.

2.4.2 *Diverging opinions among experts*

More than 50% of projections did not meet the IQR threshold, which could have been an indicator of remaining high levels of uncertainty among the experts. The highest IQR values, thereby showing the strongest divergence of opinions among the experts, were measured for the estimated probability of projection 3 (gender), projection 12 (ICT), and projection 2 (age).

Despite evidence from previous research (Scheiner and Holz-Rau 2017, Siren and Haustein 2013, 2015), experts did not collectively agree on future travel preferences differentiated by gender, within D2D journeys in 2035. One reason could be that trip chaining, as explored by Scheiner and Holz-Rau (2017) as a reason for gendered mobility behavior, is less relevant in long-haul, D2D travel. Experts stated that gender will generally be less important in the future and travel preferences will be shaped by other factors such as age, education, income, available free time, and lifestyle. However, the opposing point of view considered women would form a major customer segment in the future, providing opportunities for service differentiation among providers and opening up new revenue streams.

Experts did not always foresee ICT replacing long-haul air travel for private purposes, regardless of advantages elaborated earlier (Voronkova 2018). Whereas some imagined trips being replaced by VR and AR, partly due to increased prices for personal travel, others considered human interactions and personal experience on-site as irreplaceable. Advanced ICT was also considered to become a complement rather than a substitute, increasing the number of contacts and therefore the desire to meet in person and to explore new distant travel destinations. However, regarding business trips only, several experts estimated a decrease here due to advanced ICT, indicating that the trip purpose will still be an important component in future mobility.

Finally, experts had diverse opinions on if age would still define passengers' needs in future D2D travel. Literature suggests that age might not necessarily influence mobility behavior, due to factors such as new life stages or the down-aging effect (Garikapati et al. 2016, Siren and Haustein 2013, 2015, Wittmer and Linden 2017). These findings were not confirmed in the Delphi study. Some panelists argued that age might not be as important anymore and cultural background, trip purpose, or affinities towards specific services will drive passengers' needs. Others saw future passengers merge to one potential customer group reducing complexity. Conversely, experts also elaborated that elderly passengers have specific needs and those will continuously influence their travel, such as health status or travel budget. Particularly in an aging society, the needs of older people should be considered. For instance, autonomous driving vehicles will offer personalized D2D service to different age groups, such as to the elderly or children traveling alone, providing the possibility to participate in road traffic without the ability to drive a vehicle.

2.4.3 Cluster analysis and scenarios

To detect structure in the data, various cluster algorithms were tested, considering average probability, impact, and desirability from projections that reached the consensus threshold. Where necessary, several clustering validity indices were applied determining the optimal number of clusters in line with the majority rule by Charrad et al. (2014). After comparing resulting classifications, the hierarchical clustering (HC) algorithm, using the Euclidean distance, and ward method⁹ (Kaufman and Rousseeuw 2005, Ward 1963) proved to generate the most feasible results for this rather small dataset. Three future scenarios for D2D mobility in 2035 were developed: (1) personalized D2D travel, (2) integrated D2D travel, and (3) the game changer (see Table 2.5). These scenarios are not mutually exclusive but offer different perspectives on the future. Below, they are described in more detail, supported by the comments provided by the experts in their interviews and in the Delphi survey.

Table 2.5: Cluster statistics.

Scenario Name	Included Projection	P (mean)	I (mean)	D (mean)
1) Personalized D2D travel	1,4,6,10	6.04	5.81	5.46
2) Integrated D2D travel	5,14	6.29	6.08	5.97
3) Game changer	16	4.53	5.11	4.18

1) *Personalized D2D travel*: Scenario one describes digital-controlled future D2D travel, focusing on high personalization and customer needs. The scenario was evaluated as, on average, probable to occur with a strong impact on D2D mobility offers, and as somewhat desirable for travel providers and D2D mobility.

The overall trend of personalization and individualization was declared by the interviewed experts in the preliminary study. Journeys shall be, for instance, on-demand, flexible, and adapted towards personal preferences (projection 1). This trend was confirmed by the Delphi results. In fact, personalization and individualization are already observable today in other sectors and has started to influence mobility. In 2035, passengers will increasingly demand personalized D2D mobility. Digitalization, new technical solutions, and novel concepts of mobility (e.g., UAM) will enable this development and make it easier to cater to different needs. However, some experts have concerns that personalized D2D journeys might be too complex in terms of technology used, planning, and implementation, and too expensive to achieve by 2035. Today, long-haul air travel takes up a small market share within the overall transport sector, and personalized D2D could be even less important compared to short-haul traffic, only being relevant for business travelers and wealthy private travelers. As elaborated in Section 2.1.2, there are indicators of an increasing growth in long-haul routes (ACI 2018, Airbus 2018), which might invalidate this argument.

⁹fuzzy clustering, HC, k-means clustering, partitioning around medoids (PAM) clustering.

In any case, digitalization will support personalized travel. Internet-enabled mobility services will be the personal travel planners of passengers and completely control each aspect of their D2D journeys (projection 10). Developing a well-connected platform, allowing passengers to place all their inconvenient travel arrangements in the hands of technology in a single place, might create a new, improved travel experience. Real-time travel information and online navigation are two essential convenient aspects that will provide future passengers with significant benefits during entire journeys and will allow route optimization based on user preferences. Internet-enabled mobility services will also support seamless and intermodal mobility. Literature shows that passengers wish to receive more information on hospitality as well, such as restaurant recommendations or hotel information (Linton and Kwortnik 2019). This could also be considered to have been confirmed by the Delphi results here, as the travel planner would control each aspect of the D2D journey, including hospitality. Another aspect will be the quality of data and, in turn, the quality of services and reliability. Yet, there might be obstacles concerning the achievement of complete control of the journey, e.g., cooperation limits between operators and other factors discussed earlier in this paper.

Looking at different passenger profiles, novel working environments will influence the requirements of business travelers (projection 4). The impact of new working on corporate travel, driven, for instance, by the high growth market of the gig economy (Sinicki 2019), is huge and confirmed by interviewed experts and by the Delphi results. Flexible home office models with appropriate ICT might reduce the need to travel. On the other side, global collaboration could also promote mobility. Corporate passengers will expect a complete integration of their business life as travel time has long formed an unproductive part of working hours. This will also impact customers' preferences and the demand on public transport providers (e.g., to provide an office on rails), on airports (e.g., to provide co-working space), and in the cabin (e.g., to provide connectivity, space optimizing).

Passengers will also demand comfort and convenience along their D2D journey, such as options for sleeping and napping, or comfortable seating (projection 6). Looking specifically at long-haul air travel segments, some experts assume a reverting trend to more convenience again. As the personal comfort level during different activities and flight phases varies (Bouwens et al. 2017, Vink and Hiemstra-van Mastrigt 2011), this will enable the opportunity for further differentiation, also to avoid the trend of commoditization of transport services, such as the long-haul air segment. One also needs to distinguish between the types of traveler. The available travel budget will, next to the travel purpose, influence customer demands. There will be price sensitive passengers, already existing today (Conrady et al. 2013), but also those with a need to maximize the benefits.

2) *Integrated D2D travel*: Scenario two focuses less on differentiated products from single mobility providers, rather on collaboration to offer integrated services and create valuable travel time. It was also assessed as a probable occurrence, with a strong impact on the market and as desirable for travel providers.

Compared to scenarios one and three, the integrated D2D travel scenario was evaluated with the highest probability to occur and the strongest impact.

Passengers will increasingly demand to use travel time along their D2D journey as value-adding time, such as for working, networking, education, and other activities (projection 5). Travel is not just the mere transport from A to B, as already mentioned in scenario one, but how this time is being used. For that purpose, digitalization will be more advanced and seamless internet access throughout a journey will be a crucial requirement, as also discussed in the literature by Javornik et al. (2018). Particularly applicable to long-haul air travel, this could also mean that the reduction in travel time might not be the highest priority anymore as longer travel times with a convenient working environment could be preferable to shorter travel times. At the same time, providers along a D2D travel value chain, such as public transport, airports, airlines, and travel platforms, will increasingly collaborate to offer integrated mobility products and services (projection 14). D2D travel affects various stakeholders and the growing passengers' demand for integrated services will drive the cooperation of multiple players further. For an integrated product, collaboration will be necessary, and the efficiency of the whole transport system can only increase in line with collaboration significant players. Some of those partnerships already exist (Eurowings 2018, Lufthansa 2019). Data privacy laws, open APIs, open data, and global connectivity might enable this development. New political frameworks and guidelines (e.g., Flightpath 2050 by the European Commission (2011)) need to support in order to overcome or manage diverging interests of the multiple stakeholders to be involved. Conversely, some experts have concerns that integrating these providers in the value chain is challenging, and that costs of integration would be higher than the benefits. Some envision third party integrators acting as the customer interface providing mobility services, combining different modes – with the risk of reducing mobility companies to pure logistics providers. Scenario three will elaborate on this further.

3) *Game changer*: Scenario three contains an alternative future for 2035 towards a full monetization of the cabin by tech companies, disrupting the supply side along the travel chain and changing revenue streams for transport providers. This setting was evaluated as somewhat probable with a somewhat strong impact. Compared to scenario one and two, the game changer was the least desirable¹⁰ one for the panelists.

Airlines, public transport, and airports will mainly focus on providing basic transport services and tech companies, like Amazon or Google, will take over additional services offered to passengers, such as on-board shopping or entertainment (projection 16). Tech companies already provide a seamless and convenient booking experience today (Javornik et al. 2018). The customer interface creating a positive experience is the central value proposition here. Another business advantage for tech companies is the access to passengers' data and derived knowledge of customer preferences. Tech companies will be better positioned here and already have a head start today. In this scenario, the in-flight entertainment system will be relocated to personal devices, carried by each

¹⁰A possible desirability bias is discussed in the limitations.

passenger, being equipped with applications from tech companies containing personalized content ready to use on-board and along the entire travel chain.

These three scenarios show possible developments in the future D2D air transport market. Whereas scenario one is focused on personalization and differentiated products and services offered by single mobility providers along the travel chain, scenario two focuses more on collaboration and partnership between providers to deliver integrated offers. Scenario three downgrades mobility companies to be purely transport providers with ancillary products only accessible through collaboration with tech companies. Looking at commonalities between the scenarios, one can conclude that digitalization and personalization will be significant drivers for future D2D travel. The ‘annoying’ travel time shall be used as pleasantly as possible: either for working, relaxing, or entertainment, which will be challenging to offer at all touch points across the travel chain. Flexible use of travel time according to personal preferences might be the key in all three scenarios, also showing that the projections are interlinked with each other. In addition, one still needs to distinguish between the types of traveler (business vs. leisure), the available travel budget (low-cost vs. premium) and travel distance (short-haul vs. long-haul).

2.4.4 *Managerial insights*

Forecasting tools are essential for long-term planning. Additionally, scenarios are helpful for organizations to gain deeper understandings of potential future business environments (Sarpong and Amankwah-Amoah 2015) and hence make long-term plans. Findings from all three scenarios reveal possible future developments and can support the work and decision-making process of strategy departments, customer experience units, and product development processes departments of mobility firms, along the entire travel chain in this new paradigm. However, not all mobility providers might be equally affected by each scenario.

1) Personalized D2D travel: As the personalization and heterogeneity of passengers’ needs will become increasingly important in this scenario, gaining knowledge about future D2D projections seems crucial and of high practical relevance, for the entire mobility industry, in order to adapt and innovate D2D products and services towards main passenger groups and their respective needs. The strong demand for personalization will be beneficial for suppliers, as they finally know their customers’ destinations, routings, and service expectations. Due to many differentiated customer requirements, such as in the business context or regarding comfort and convenience, providers along the travel chain have many opportunities to position individualized products and services, also through partnerships. They might turn such amenities into key differentiators, especially for the premium D2D mobility market while also offering a menu of options, ranging from cheap (standardized) to expensive (individualized) products and services. Access and egress transport providers like public transport, railways, long-distance bus services, and taxis can offer basic, low-cost transport targeting price sensitive customers but also premium,

highly customized mobility options with on-board amenities to enhance the travel experience or to enable work during travel. Likewise, airlines could consider such tailorable offers. Seat classes could be replaced by a basic transport seating system for every passenger, additionally equipped with bookable ancillary services and in-flight retail if required. In this way, customers' needs could be fulfilled to the maximum, while avoiding costs for unused services. As the entire value chain could be affected by this scenario, original equipment manufacturers (OEMs) would already start to support this trend with building flexible cabin systems and aircraft seats meeting minimum standards of each passenger.

Internet-enabled mobility services improve the customer experience. As described by Linton and Kwornik (2019), there is currently a supplier–user gap, partly as it is challenging to keep information on mobile devices up to date. Incompatible systems, unwillingness to share data, and privacy protection are also identified as existing bottlenecks for creating a D2D travel assistant. To stay competitive, technical solutions are necessary to cope with these challenges. Due to the D2D scope, each transport provider would need to work equally towards this goal as the quality of data and in turn the quality of services and reliability will be the essential success factor.

2) Integrated D2D travel: Compared to scenario one, providers in scenario two should not just exchange data but work in partnerships. Collaboration would enable offerings of integrated, D2D mobility products and services, increasing the travel experience for passengers and creating seamless and intermodal D2D mobility. Some D2D partnerships already exist, as discussed. Additional collaborations, such as between airlines, airports and public transport providers or airlines and the hospitality sector could increase seamless D2D travel further. Examples could be the support of passengers in managing disruptions due to delays within one travel segment with automated check-ins or rebooking services.

As the actual travel time shall be spent in a value-adding way, there is also a lot of room for improvement, new business opportunities, and the construction of unique selling propositions (USPs): offerings of ancillary services, dedicated spaces at the airport (office, playground, spa, etc.), and other touch points people come across along their journeys. In the D2D context, creating value-adding travel time could also mean reduced waiting times at airport security, for boarding and for connections, as currently passengers cannot always use that time efficiently. Applicable to airlines and the long-haul flights, the reduction in travel time might not be the highest priority anymore, which could enable lower aircraft airspeeds, resulting in operational cost savings and emission reductions.

3) Game changer: Although this scenario is assessed to have the lowest probability, it could be considered a black swan scenario, transforming the market dynamics in the transport industry. It raises the question who will obtain the customer interface and earn on future passengers. The supply side should appreciate the business advantages of tech companies for organizational learning and business development purposes. Several experts assess this develop-

ment as a growing trend, and it might be an alternative scenario particularly if airlines do not manage to change their roles to real D2D mobility providers, including next to transport services additional entertainment and hospitality offers. In fact, some already try to oppose this trend and invest heavily to stay in the game. In this context, there might also be a cooperation with ICT companies to provide the best offers to passengers, subject to their individual needs. Eventually, such cooperation could also increase ancillary revenues.

2.5 LIMITATIONS AND CONCLUSION

2.5.1 *Limitations and future research*

There are several practical ways to improve this Delphi study, including the improvement of the overall response rate. Since many corporate e-mail addresses have been approached for this study, e-mails with the word document attachment could have possibly gone into spam resulting into a lower response rate. However, literature also discusses that word document surveys may also create advantages, such as the personal approach via e-mail and the user-friendliness of the format compared to more complex online tools (Belton et al. 2019). The dropout rate of 12% in the second round was probably due to the holiday season with Christmas and New Year's Eve at the time of the survey. Due to self-interests of experts leading into possible desirability biases, the expert panel composition of this Delphi study needs to be assessed critically (Ecken et al. 2011, Melander et al. 2018). Looking at the segmentation of participants, one can see that 42% of experts come from academia, thus exceeding other segments. That might be due to the cooperativeness of scholars for taking part in such a study or based on the fact that personal networks were partly used for approaching experts. Such expert distribution could lead to biases; however, one could also argue that scholars possess a comprehensive overview of the topic of D2D mobility. As there are only two airline representatives as interview partners in the preliminary study and one in the Delphi, one could discuss the underrepresentation of airlines in the expert sample. Additional experts from airlines were contacted but, unfortunately, could not be won over for participation. Other experts from the area of management consulting do also know the aviation industry very well and their estimations are included in this research. At the same time, consultants as experts could also be seen rather critical, as they might try to shape results towards their business advantages. Another desirability bias could be explained by the rather low desirability for scenario three ($D = 4.18$). According to the game changer, transport providers would be downgraded to pure logistic providers, handing the interface to passengers and parts of their business to tech companies. However, tech companies are not included in the sample and D2D transport providers might hence assess this scenario as rather undesirable.

Generally, the Delphi technique is not an approach on its own but part of a wider research process (Rowe and Wright 2011). Results may not be generalizable or enable theory building but rather provide insights into possible future developments (and to future-related questions otherwise difficult to address),

depicted here in the three scenarios. Further research needs to be conducted to explore results in more depth and to balance out limitations of the future-oriented research method for enhancing utilities.

The year 2035 has been identified as an appropriate focus year for this Delphi study. One could also perceive this time frame to be too far removed from today, especially with technology and working environments advancing at an unforeseeable speed and new policies and laws to come. Further research could incorporate the replication of this Delphi survey with another focus year, such as 2025. Other markets (next to the European scope) could also be explored.

Passengers representing the demand side are essential stakeholders in the transport sector and were not included. That is due to the fact that this Delphi study aimed to focus on the assessment from the supply side (mobility provider). A complementary further study incorporating the demand side could be an approach for further research and comparison of results. A parallel Delphi study, such as done by Spickermann et al. (2014a), would also be possible as a next research step. One could argue that the definition of D2D mobility can be expanded with additional stakeholders. Looking specifically at scenario three, the present panel could be complemented with experts from the hospitality industry, the tech industry, or from travel platform providers.

Further research is also possible by examining if companies today are already acting upon these identified future projections. Possible methods for conducting such trend testing analysis could be surveys, interviews but also data science techniques to provide quantitative results. Single projections could also be explored in more detail. For instance, projection 8 (eco-friendly journeys) is estimated as only 'somewhat probable' but as the second most desirable development according to the experts. As environmental aspects were seen as one major challenge for the overall transport system by several of the interviewed experts, and as of recent, are gaining increasing attention from broader society and political institutes, it might be important to explore the rationale behind this contrary result.

2.5.2 *Summary*

This paper presents findings from a Delphi survey, with 38 experts, on the assessment of 17 projections, concerning the question of what future D2D air travel in Europe could look like in 2035. The study tried to capture possible future projections on the D2D air travel market, considering trends from both the supply and demand sides. The Delphi was modified with results from a preliminary study, combining semi-structured expert interviews (N = 18), a literature review, and an exploratory workshop. Hierarchical clustering was applied to develop three future D2D mobility scenarios for the year 2035. Managerial insights, the limitations of this approach and future research were discussed. The research goal was two-fold: first, to identify projections that gained consensus and second, projections with dissent among experts. Several projections developed from the preliminary study, which also have foundations in previous research, were confirmed in the Delphi. The paper had also proven

that the Delphi technique can be used as a feasible tool to capture potential D2D mobility projections and to develop future mobility scenarios.

Overall, future projections cannot be seen as isolated but interlinked. Findings also reveal that the passenger type, origin, the available travel budget, and travel distance still need to be taken into consideration when thinking about future D2D air travel. Digitalization and personalization will be the key drivers of D2D mobility in the long-haul market. Looking at the travel market, some projections can already be observed today, such as the overall trend for the personalization of products and services. Moreover, travel will not be just the mere transport from A to B anymore. Passengers will demand to spend their travel time in a value-adding way, such as working, relaxing or being entertained. Here, other additional activities are possible and might open up new business opportunities, such as for tech companies. Conversely, there is still disagreement between the experts regarding gendered travel preferences, ICT as a replacement of private long-haul journeys, and on the weight of age as an influencing factor on future travel needs.

To sum up, companies along the D2D air travel value chain face a variety of challenges and are urgently advised to adopt measures aimed at the personalization and digitalization of journeys overall and to establish partnerships with other providers and tech companies.

Lessons learned from a two-round Delphi-based scenario study¹

3.1 METHOD DETAILS AND CO-SUBMITTED RESEARCH

3.1.1 *Overview of Delphi method*

The Delphi technique, first proposed in the 1950s, was developed by the RAND company (Dalkey and Helmer 1963). It is an anonymous survey technique conducted in several rounds for structuring group communication. Panel participants are asked to assess projections (also called Delphi statements, questions or hypotheses) repeatedly (Linstone and Turoff 1975, 2011). The Delphi method has four key characteristics: anonymity, iteration, controlled feedback, and statistical "group response" (Rowe and Wright 2001). Beyond the classical Delphi approach (Dalkey and Helmer 1963), different types exist, such as the nominal group technique, decision Delphi, policy Delphi, and the argument Delphi (Hasson and Keeney 2011, Miles et al. 2016). It is a suitable technique for answering prospective research questions of what the future might look like (as done in this study) and for instance to assess the expected probability, desirability and expected impact of projections or scenarios. The technique can also focus on current challenges, such as be used to rank and prioritize topics, support policy making, generating ideas, establishing facts, and for other research purposes. Items can also include an assessment on the feasibility, urgency for action, or innovativeness. It is applied mainly in the fields of healthcare, education and business research, with a significant increase in Delphi studies since 2005 (Flostrand et al. 2020). An overview of the most cited papers across the disciplines is provided in the Appendix (see Table A.2). Depending on the study type, the Delphi method follows a qualitative, quantitative or mixed-methods approach (Miles et al. 2016). The technique can be combined with other methods, for instance to complement the development of projections or to support the analysis of results. There are also differences in the optimal number of panelists, number of rounds, consensus measurement, types of feedback loop and other parameters, giving rise to numerous modified Delphi versions (von der Gracht 2008, Miles et al. 2016) that we believe may be overwhelming for researchers. Over the last decade, various papers have discussed the conduct of Delphi studies from a technical point of view to support researchers. Some focus on specific research steps. An overview of technical papers is provided in the supplementary material (see Table A.1). Most lessons learned papers were published around 2011, and fewer have been published in the last five years (Belton et al. 2019, Gray and Morris 2016, Hirschhorn 2019). Others focus on

¹This chapter is based on Schmalz et al. (2021e): Schmalz, U., Spinler, S., Ringbeck, J., 2021e. Lessons learned from a two-round delphi-based scenario study. *MethodsX* 8, 101179. Parts of this study were conducted within the CAMERA-project and many thanks go to the consortium. CAMERA (2019) has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 769606.

specific steps in the process, such as the panelists' selection (Mauksch et al. 2020), or the Delphi questionnaire (Markmann et al. 2021). However, much has changed in recent years, with modifications to the Delphi technique, including improvements to data analytics, the application of classic theories to development of projections, and tools to support qualitative text analysis of panelists' comments. We consider the Delphi technique to be applicable to a wide range of disciplines and a suitable method for experienced, early-career and postgraduate researchers. This technical paper provides additional practical insights for the research community, and complements the literature by providing (1) a discussion of lessons learned from conducting a two-round Delphi study, with practical, step-by-step guidance, and (2) a replicable approach for scholars, including those incorporating scenario developments into their research. We focus on issues regarding the acquisition of experts and panelists, the literature review, development of the Delphi questionnaire, execution of the study, scenario development, and managerial implications for creating practical relevance. We also describe from our own experience and lessons learned on how online social networks, data analytics and research tools such as NVivo can support researchers conducting Delphi studies. We suggest what we would do differently if we were to conduct this or another Delphi study again.

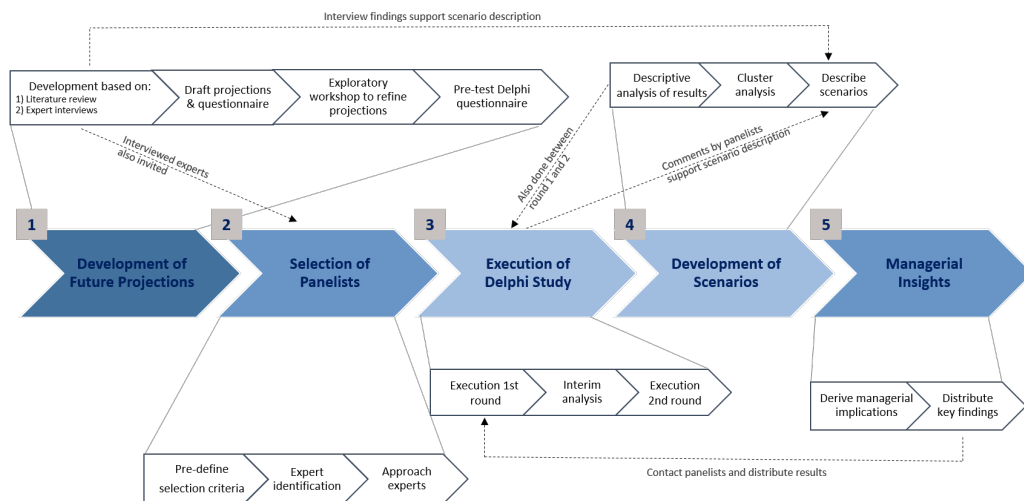


Figure 3.1: Five-step research approach for a two-round Delphi-based scenario study (adapted from von der Gracht and Darkow (2010) and Kluge et al. (2020)).

3.1.2 Co-submitted research

This technical paper is based on a Delphi-based scenario study examining the future of D2D passenger air travel in 2035 (Kluge et al. 2020). Today's ever-changing and connected world, with increasingly fragmented customer requirements, also affects the travel industry. Understanding future developments, passenger needs and possible scenarios is crucial for long-term planning and decision-making in the mobility sector. In the context of this Delphi study, intermodal D2D air travel is concerned with the entire travel chain, from the point of origin to the final destination. This definition includes not only the air

travel segment, but also all access and egress modes to and from the airport, as well as transfers within the airport. Hence, D2D air travel is of high practical relevance to airlines, airports, public transport providers and others. The D2D view on air travel is novel, as many modes have tended to focus only on their own segment or considered D2D travel purely in the context of urban mobility. Applying the D2D view may help to improve the entire travel chain for air travel passengers, for example by creating seamless, intermodal travel or managing disruptions. Our study is particularly concerned with future projections that affect all (or most) aspects of the travel chain, such as digitalization and personalization. However, little is known about what the future might look like in this context. Applying the Delphi technique helps shed some light on possible future D2D air travel scenarios, and enables the inclusion of multi-stakeholder panelists, encompassing the desired scope of multimodality.

3.1.3 *Aim and structure of this technical paper*

Kluge et al.'s (Kluge et al. 2020) co-submitted study followed a five-step research approach²: 1) development of future projections, 2) selection of panelists, 3) execution of the Delphi study, 4) development of scenarios, and 5) managerial insights (see Figure 3.1). This paper is structured according to these five steps, systematically describing the entire research process with technical details. As depicted in Figure 3.1, the research steps are interrelated. For instance, findings from the expert interviews in step one are also used at a later stage for the description of scenarios in step four. At the end of each sub-section, we summarize our lessons learned, in which we present our personal experiences, and aspects we could have improved with hindsight. In doing so, we aim to provide helpful practical recommendations for planning and conducting a Delphi-based scenario study.

3.2 DEVELOPMENT OF FUTURE PROJECTIONS (STEP ONE)

The first step involved developing future projections for testing with the Delphi questionnaire, using three qualitative methods: 1) a literature review, 2) expert interviews, and 3) one workshop. Drawing on various sources to develop projections enabled triangulation of methods and ensured that no key topics relevant to the field of study were omitted from the projections. Including industry representatives in the interviews aimed to gain a practical view of the studied topic.

3.2.1 *Literature review*

The literature review provided a theoretical background for the projections assessed in the Delphi study. Hence, we consider this step to be indispensable in a Delphi study. We applied Webster and Watson's (Webster and Watson

²In the co-submitted research paper, we refer to a four-step approach and use the term "pre-study" in the context of step 1, which is not used here. In this technical paper, the research steps are presented in more detail.

2002) recommendations for conducting literature reviews. We aimed to examine the latest academic papers on trends around general mobility, D2D travel and air travel, focusing on two key questions: which trends will influence current and future travel in the D2D context; and how will travel behavior and customer needs change? Using predefined keywords (further developed during the review), we searched the Google Scholar, EBSCO, ABI/INFORM and Scopus databases. We focused on the European market, on leading journals and conference proceedings, and on work published within the last eight years (2010–2018). During the review, we were able to detect high-level trends across studies, such as digitalization and mobile communications, demographic changes and gender differences. These formed the basis for developing the projections.

We also conducted a second literature review of previous Delphi studies on the future of mobility and transport. We identified eight papers and studied their methodological approach and research results. This was helpful for improving our knowledge of applications of the Delphi technique in mobility research, and for gaining insights into potential mobility scenarios and trends. We also created an overview table of previous work, listing author(s) and year, the scope of each study, time horizons, numbers of projections, panelists and rounds, response rates and details of the research. This table was included in the co-submitted paper to provide readers with a systematic summary of previous work.

3.2.2 *Expert interviews*

We used interviews in our Delphi study to identify future D2D travel trends and to gain insights into potential future mobility in Europe. The interviews also helped us to develop projections connected with real-world challenges and opportunities in the mobility sector. We designed an interview guide and conducted a test interview with two mobility researchers, as recommended in the literature (Burke and Miller 2001). After testing and receiving feedback from the test interviewees, the guide was adapted to reduce its length and clarify some wording. The interviews were exploratory in nature, and the guide was used to support a natural conversation rather than creating an interviewee–interviewer situation. We expected that this would uncover topics that we had not previously considered. The final interview guide and the main objectives are presented in the Appendix (see Table A.3). We initially contacted 55 experts via email, 18³ of whom agreed to an interview (33% response rate). Our email request incorporated the objective of the interview, an introduction to our research facility, contact details, and information on data usage and storage. As the interviews were part of an EU-project⁴, we also included details of the project. We conducted 18 semi-structured interviews with experts from industry, such as airlines, airports and public transport providers, and with other

³Other Delphi studies conducted between 14 and 18 interviews (Firth et al. 2019, Jiang et al. 2017, Toppinen et al. 2018). Hence, we considered 18 expert interviews for our Delphi study as sufficient and a valid number in line with the literature.

⁴17 of the 18 interviews were conducted as part of CAMERA (2019), an EU-funded project (GA 769606, H2020).

mobility experts who were familiar with the topic of D2D air travel. Figure 3.2 illustrates the distribution of the sample. As the scope of our research was on D2D air travel, it was essential to interview representatives of different modes of transport to create this D2D view. Our focus was on the European market, so we approached experts from various European countries, including Austria (N = 1), Belgium (N = 1), Switzerland (N = 1), Italy (N = 1), the Netherlands (N = 1) and Germany (N = 13).

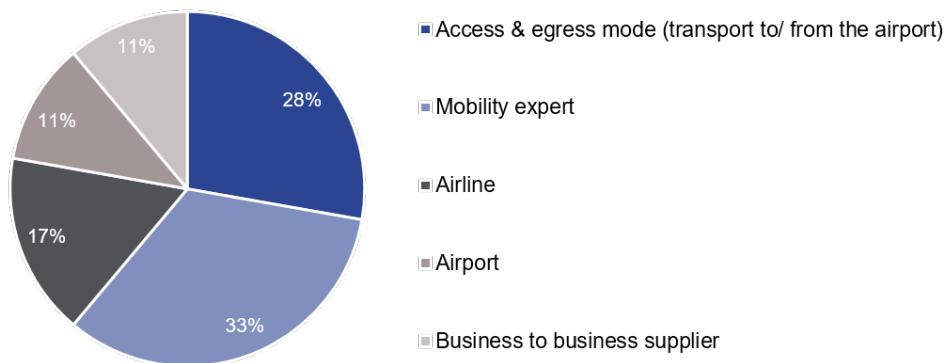


Figure 3.2: Interviews: distribution of sample (adapted from Paul et al. (2018)).

The interviews were conducted face-to-face or by phone. After obtaining consent, they were recorded and transcribed following Kuckartz's rules for transcription (Kuckartz 2014), which focus on content rather than subjective views or perceptions. Analysis of the interview data was based on Mayring's summarizing and inductive category formation approach (Mayring 2014). We used Microsoft Excel, which can be time-consuming. Findings from the interviews were used to develop a draft list of future projects and to develop the scenarios in research step four (see Section 3.5 "Development of scenarios (step four)"). All 18 experts interviewed were invited to take part in the Delphi rounds, but only six did so, which may indicate low involvement by some interviewees, although some were constrained by holidays and lack of time.

3.2.3 Future projections

Having consolidated our findings from the literature review and interviews, we developed key points and 51 draft projections for the Delphi questionnaire. Pre-tests can help to improve the comprehensibility and reliability of Delphi questionnaires. A workshop was conducted with two mobility researchers to discuss and revise the first list of projections. Delphi panelists should not be required to invest too much time in each round, as this may increase the dropout rate. In our study, a list of 17 projections proved to be sufficient. As a result of written pre-tests with two further mobility researchers (neither of whom participated in the interviews or the Delphi questionnaire), a seven-point-Likert

ordinal scale was used, as this scale seemed to provide an adequate answer range. Along with the questionnaire, it is also advisable to provide a cover letter, contact details, and a scenario with GDP growth rates and other assumptions. In the questionnaire, the projections were assessed for probability (P), impact (I), and desirability (D). These assessment scales made most sense for our study as we focused on a practical question and the industry impact and desirability were of high interest. Additional scales would have increased the questionnaire length and potentially result into higher dropout rates. The same scales (P, I, & D) were also used in Delphi studies with a transportation scope (Fritschy and Spinler 2019, Schuckmann et al. 2012). Panelists were able to leave short comments on their evaluations (optional). We tried to use simple wording, and provided examples when necessary. Each projection started with “In 2035 . . .” to remind panelists of the year in scope. We used Microsoft Word to develop the questionnaire in the first and second rounds. An extract from the first-round questionnaire is provided in Figures A.1, A.2 and A.3 in the Appendix.

One aim of the Delphi method is to shed light on prospective research questions by casting uncertainty in a few concrete scenarios. The year 2035, which was 17 years away in 2018 when our study was conducted, was selected as an appropriate time horizon for two reasons. First, 2035 was imaginable for the experts to make assessments, but sufficiently different from contemporary travel. Second, the mobility sector conducts long-term planning, so projects in around 17 years’ time might provide sufficient time to implement managerial recommendations. More distant time points, such as 2050, would not have fulfilled these two conditions. The literature review also revealed that such time frame was commonly used in other transport-related Delphi studies (e.g., von der Gracht and Darkow (2010), Schuckmann et al. (2012), Spickermann et al. (2014a)).

3.2.4 *Lessons learned from developing future projections*

- The literature review could have been more systematic. Weißer et al. (2020) leverage the power of data analytics (topic filtering and clustering) to identify key topics in a large amount of textual data. This approach may support the detection of relevant trends and preselection of papers for further review, and has gained momentum in recent years. We recommend that researchers should consider data analytics in order to save time and resources, and analyze the literature systematically.
- Our literature review provided the theoretical framework for our Delphi study. Other Delphi studies rely on the application of a theory, such as the diffusion of eco-innovations theory (Anderhofstadt and Spinler 2019) or the organizational information processing theory (Roßmann et al. 2018). In retrospect, we should have used an underlying theory next to the literature review to increase our study results further.
- The use of workshops in the research design could have been expended. As done by Spickermann et al. (2014a), we could have conducted more

workshops to refine projections further but also to derive stakeholder recommendations in step five. Workshops can be conducted with researchers but also with panelists. Saving resources, workshops could also be conducted online.

- It can be time-consuming to get confirmations for interviews. Friendly reminders and (multiple) follow-up emails may help secure positive replies. Our personal networks, and even very loose ties, also helped to bring experts on board. On the other hand, leveraging personal networks, sometimes known as friendomization, may create biases. One bias may have been the geographical distribution of our sample, as explored below. Incentives can also be helpful, as discussed in Section 3.6 "Managerial insights (step five)".
- Our interview sample may have been biased. We tried to create a diverse sample of interviewees from various European countries. However, many interviewees were located in Germany ($N = 13$), probably because all the authors are German. This may have led to biases in the answers, as transport systems differ at a country level. Such biases must be acknowledged as part of the research process. However, we expected that the interviewees would have the necessary expertise to answer our questions from a broader European point of view, excluding their own biases.
- Transcribing interviews is time-consuming but very important. We encourage researchers to carry out the transcriptions themselves, as this helps in-depth analysis of the interview data. Notes and memory protocols only save fractions of the content. As our analysis of the interview transcripts using Microsoft Excel was very time-consuming, programs that are more practical for analyzing large amounts of textual data are recommended, such as Atlas.ti or NVivo. Text-mining techniques, such as topic modeling or building a document-term matrix (DTM), might also be leveraged at this stage to analyze the interview transcripts systematically.
- Interviews might have been considered for the first Delphi round. As described above, we had too many interviewee dropouts after the first round with the Delphi questionnaire, and therefore decided against this.
- The framing and tense of the Delphi questionnaires could have been improved. All questions should be formulated positively or negatively, and if these are mixed, the questions should be recoded in the data analysis. We formulated all projections in the future tense; however, the present tense may be more suitable, especially when the time horizon is provided. We encourage researchers to check these issues before distributing their Delphi questionnaires.
- The actual time needed to fill in the Delphi questionnaire may vary. We received mixed feedback from the panelists on the number of projections. Although pre-tested several times, some panelists considered the questionnaire to be too long and time-consuming. One panelist canceled the

process as it took too much time. We encourage researchers to keep their questionnaires as short as possible. However, this may conflict with collecting sufficient amounts of data. To avoid long questionnaires, it may also be advisable to define the scope of the study clearly, and to clarify any basic assumptions beforehand.

- Alternative questionnaire formats may have advantages for researchers. Analyzing a Word document, transferring the results into table format for analysis, and preparing the second round personalized for more than 40 panelists can be very time-consuming and prone to errors. As an alternative questionnaire format, we recommend considering the RTD format (Gordon and Pease 2006) (using a platform) and/or sending an url. The RTD also has other advantages, such as immediate feedback. Examples of the use of RTD in mobility research include Julsrud and Uteng (2015) and Spickermann et al. (2014a). However, such platforms may be costly.

3.3 SELECTION OF PANELISTS (STEP TWO)

Before approaching panelists for our Delphi study, pre-selection criteria were defined. Panelists should come from diverse backgrounds to mitigate biases (Bonaccorsi et al. 2020). As we focused on D2D air travel, we tried to capture this scope through an appropriate selection of panelists (see also Section "Expert interviews"). We included panelists working not only in aviation, but also at airports, as ground-transport providers (providing mobility transport to and from airports), and in the broader mobility sector. Ten stakeholder groups were identified for the panel, representing all main travel segments. As all sub-groups were part of the mobility industry more broadly, the Delphi exercise was still conducted with a single industry panel (Förster and von der Gracht 2014). Additional selection criteria were a minimum of two years' work experience in the mobility industry, and a European working scope. All panelists were anonymized in the results. Potential panelists were identified by leveraging our personal networks, scanning conference lists and searching LinkedIn. All contacts were tabulated, with information on name, country, position, contact details, whether or not they returned the questionnaire in rounds one and two, and general comments. Each panelist was assigned an ID⁵, starting at 1. As the panelists' overviews contained personal information, they had to be stored with extra care, accessible only to the researchers. A total of 113 people were contacted via email, 16 of whom declined the request, mainly due to personal time constraints, extended absence or self-assessing themselves as having insufficient expertise. Eight panelists who agreed to participate either did not return their questionnaires at all, or submitted responses with too many missing values. Forty-one people did not respond, and five people could not be contacted owing to incorrect email addresses. In total, 43 panelists participated

⁵The IDs were used in the research process to save personalized questionnaires in the second Delphi round, to maintain the anonymity of returns, and to work with the data set. To detect the panelists' names, it was necessary to access the panelists' overview table, which was stored securely.

in the first round, leading to a response rate of 38%⁶. As five of these dropped out in the second round, the overall response rate was 34%. Figure 3.3 provides an overview of the final panel. Thirty-one panelists assessed their expertise for assessing the questions as 'high' or 'very high'. Hence, we assumed a valid selection process and suitable panelists for our Delphi study. The panel was also diverse in terms of job position and gender distribution. As this study was conducted in the male-dominated mobility sector, we considered 39% female panelists to be a good result.

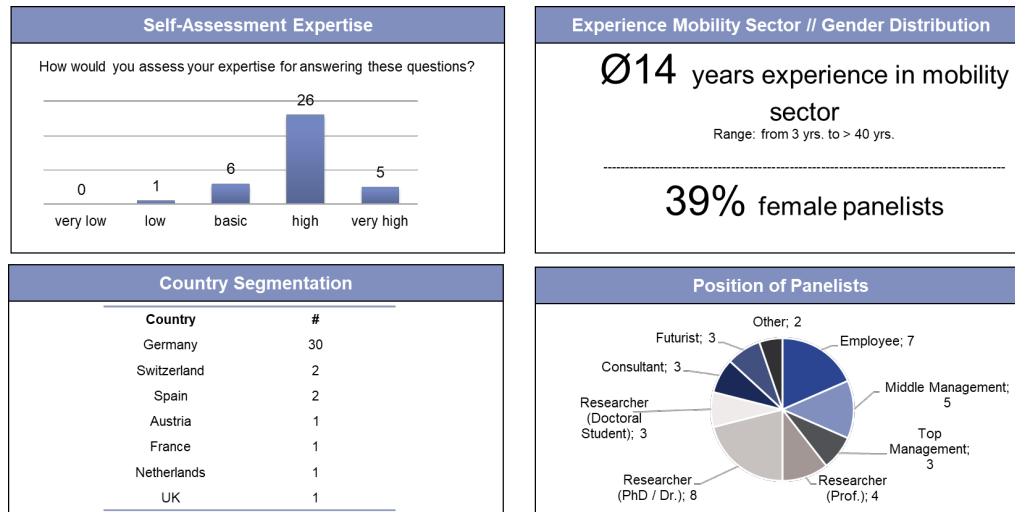


Figure 3.3: Overview of final panelists.

3.3.1 Lessons learned from selecting the panelists

- Biases might occur at any step of the research process and should be acknowledged. As already discussed, leveraging personal networks to acquire panelists may create bias (Mauksch et al. 2020). Figure 3.3 shows that our panel was German-heavy, as previously identified in Section "Expert interviews". Additionally, panelists might have been more involved due to personal connections with the research team. Conversely, selecting a diverse panel (different age, gender, positions, companies etc.) is a strategy to mitigate biases (Bonaccorsi et al. 2020).
- We focused in our panel selection on the "surface-level variables", such as age, gender, or job position (Spickermann et al. 2014b). Additionally, we recommend exploring "deep-level diversity criteria", such as personal values or beliefs, as explored in an experiment by Spickermann et al. (2014b). Deep-level criteria can potentially affect the panel diversity and response behavior of participants. Conversely, it might be difficult to explore deep-level criteria and require further questions and / or prior knowledge of the panelists. Mauksch et al. (2020) provides a recent review of tools for the selection of panelists.

⁶Similar offline (vs. RTD) and two-round Delphi studies show a response rate of 42% and 43% (von der Gracht and Darkow 2010, Mason and Alamdari 2007). Hence, we considered our response rate as sufficient.

- Online social networks are suitable channels for researching and selecting panelists. LinkedIn provides sufficient information to decide whether someone is knowledgeable and might be considered to be an expert (based on work experience, professional field, etc.). Depending on the study's scope and research question, other online social networks might be considered as alternative sources, such as Instagram, Facebook or industry-focused networks (including conference lists, also partly used in our study).
- Selecting and approaching panelists generates personal data, including names, levels of expertise and email addresses, as well as private information such as times of absence (e.g., through receiving out-of-office replies). We advise researchers to be extremely careful with such data, even after the study has been conducted. Data must be stored securely at all times, including when projects have ended and papers have been published. There are several ways to store private data, for example through password protection. Personal data may also be deleted after some time, although this should be checked against the terms and conditions of project partners, employees, universities, publishers, etc.
- After executing the Delphi study, we only contacted the panelists to distribute the results. The panelists agreed to take part in the Delphi study, but not to receive newsletters, invitations or other non-study-related content. Only two panelists explicitly contacted us afterwards to keep in touch.

3.4 EXECUTION OF THE DELPHI STUDY (STEP THREE)

We approached the panelists via a short email message, which introduced our study and specified the deadline for return. The questionnaire was attached as a Word document in read-only format⁷. We allowed a minimum of two weeks for panelists to return their questionnaires. We sent email reminders, and telephoned the panelists to ask for their assessments. Delphi rounds can be repeated until consensus among panelists is reached. In our case, two rounds were sufficient. We were also interested in projections that created dissent among the panelists. These diverging assessments were interpreted as uncertainty among the panelists with respect to particular projections. These findings provided interesting insights and were discussed separately in light of the current literature. We also wanted to avoid the risk of a high dropout rate in a potential third round. In the interim analysis between rounds one and two, we checked the raw data for any errors (missing values or double answers). When errors were identified, we reached out to the panelists and requested corrected estimations. This enabled us to include as many questionnaires as possible. We received 504 qualitative comments in the first round, which might have been overwhelming. Similarly to Schuckmann et al. (2012), we divided all the comments into two subgroups containing supporting or non-supporting arguments. This was carried out in Microsoft Excel using a simple table format. For the quantitative analysis, we conducted descriptive statistics in R and cal-

⁷Read-only formats still allow questionnaires to be filled in.

culated the mean, median, standard deviation and IQR. R, a statistical software package, is suitable for analyzing Delphi data as it is open-source and free, easy to use (even for beginners), replicable with the use of codes, and based on packages, allowing continuous improvement and hands-on analysis. Among other measurements, the IQR ($Q_3 - Q_1$) is a common consensus measurement widely used in applied Delphi studies, as highlighted in von der Gracht's literature review (von der Gracht 2012). It depicts 50% of assessments between the lower quartile (Q_1) and upper quartile (Q_3). We applied a threshold of $IQR \leq 1$ to detect which projects gained consensus. These were used for the scenario development at a later research stage. Projections with the highest IQR attracted the most divergent opinions and were discussed separately, providing further interesting insights. No data standardization was necessary, as the same (7-point Likert) scale was used for all answers. Boxplots provided a quick and easy visual summary of the data, and allowed outliers to be identified. Scatter plots provided a first indication of possible clusters. Although we used an ordinal scale to assess the projections, we conducted descriptive statistics to reflect on the spread of answers among panelists. The standard deviation and the change in standard deviation (in%) between the first and second rounds were interpreted as indications of the level of convergence in panelists' assessments. A convergence was also supported by panelists' comments in the second round. Histograms of the mean, minimum and maximum depicted the distribution of answers at a quick glance. The second-round questionnaire was again constructed in Microsoft Word. Panelists received controlled and personalized feedback in the form of the spread of the aggregated group response in histograms, including their own estimations, and a summary of the rationale for the group response (taken from panelists' comments). An example of projection one is given in Figure A.4 in the Appendix. We also sent them feedback on all the projections, including those that had already reached consent in the first round. In light of Delphi's characteristics, the panelists had an opportunity to compare their own estimations and to reconsider their answers based on the group response of the entire panel. Having made their assessments, they returned their questionnaires by email to the researchers.

3.4.1 *Lessons learned from executing the Delphi study*

- Conducting a Delphi study is a slow process. Receiving feedback and returns may take several weeks, so a long period for data gathering must be considered in planning projects. Hence, we advise researchers to plan a suitable back-up period in case returns are slower than expected. It is also advisable to return the controlled feedback in the second round as soon as possible to maintain momentum. Conversely, the required time might also depend on the sample size, type of experts, access to experts, and researchers' networks.
- Timing is important. To avoid a low response rate, the questionnaire distribution should not overlap with holiday periods, such as summer break or Christmas. Spring and autumn are ideal seasons for data gathering.

- Qualitative data in Delphi studies can be analyzed in systematic ways. Text-analysis software can be used to support the execution of a Delphi study. Our study required analysis of a large amount of qualitative textual data (panelists' comments). As previously discussed, investment in a software package for qualitative data analysis may support the research process. Roßmann et al. (2018) applied a content analysis approach and coded the qualitative comments by two human coders using pre-defined units. Applying grounded theory, von Briel (2018) derived core statements by coding panelists' responses to open-ended questions from a first Delphi round. These core statements are used as input for the second Delphi round.
- Various consensus measurements are possible and should be applied. We used the IQR because it is widely used in applied Delphi studies. However, other statistical indices are available for measuring consensus, agreement and association (Meijering et al. 2013). Dajani et al. (1979) provide termination (or stopping) criteria for Delphi rounds by testing the stability with the χ^2 -test. The level of agreement in our data might have differed if we had chosen different indices. In retrospect, we should have used more indices to test our data, the stability and to compare results.
- We consider projections that did not receive consent among the panelists as valuable findings. Although not used for further scenario development, we believe that these projections can be discussed as developments that lead to high uncertainty.

3.5 DEVELOPMENT OF SCENARIOS (STEP FOUR)

The scenario development approach on its own is already well established as a suitable foresight method in many disciplines (van der Heijden 2011). As shown by Nowack et al. (2011), many Delphi studies are used for scenario building. Scenarios help to shed light on what the future might look like. They help researchers to communicate findings in a descriptive, easily understandable way for readers and practitioners. To create scenarios for the possible future of D2D air travel, we conducted a cluster analysis in R, using data on seven projections that reached the IQR threshold. For this, we used the means of the assessed probability, impact and desirability of each projection. A detected cluster was considered as a scenario on its own. Various algorithms were available, and the results of different cluster approaches were compared to determine the most feasible results. We applied fuzzy c-means (FCM) clustering (Bezdek 1981), k-means clustering (MacQueen 1967), PAM clustering (Schubert and Rousseeuw 2019), and HC (Kaufman and Rousseeuw 2005, Miles et al. 2016). Prior Delphi studies applied mainly fuzzy clustering (e.g., Fritschy and Spinler (2019), Roßmann et al. (2018)) and HC (e.g., Linz (2012), Tapio (2003)). To detect the optimal number of clusters (required for some algorithms but not needed for HC), we applied Charrad et al.'s majority rule (Charrad et al. 2014) using the *NbClust package*. With seven confirmed projects, our data set was rather small. A higher IQR-threshold might have increased the data set.

According to von der Gracht (2012), studies with more answer options (e.g., a 10-point Likert scale) may enlarge the IQR-threshold. However, this did not apply to our study. A scatter plot provided a first visual indication of possible clusters. The research team compared the results of all cluster algorithms described above and selected results that provided meaningful clusters. Fuzzy, k-means and HC clustering generated the same clusters. We decided on HC, as Akman et al. (2019) argue that it is a suitable cluster algorithm for a small data set. Hence, HC with Euclidean distance and using the Ward (1963) method provided the best and most feasible results for our study. Our R code is attached in the Appendix (see A.3). We developed three clusters leading to three separate scenarios: 1) personalized D2D travel, 2) integrated D2D travel, and 3) the game changer. The average probability, impact and desirability of each developed scenario are depicted in Table 3.1. A dendrogram displaying the three cluster assignments in the nodes is presented in Figure 3.4. To describe the scenarios, we mainly utilized panelists' comments from the two Delphi rounds, including supporting and non-supporting arguments. Findings from the literature review and the expert interviews in step one supported the development when appropriate. For instance, an expert might provide a good description of a projection concerning the value-added use of travel time. Scenario 1 (personalized D2D travel) and scenario 2 (integrated D2D travel) are not mutually exclusive but have different foci. Scenario 1 is concerned with high personalization of journeys, whereas scenario 2 focuses on partnerships. Scenario 3 (the game changer) is a black swan scenario: if it were to become reality, it would have the potential to seriously disrupt the aviation and travel industry. All three scenarios depict a possible future. However, some trends, like digitalization and personalization, relate to all three scenarios. Other scenario studies might develop scenarios that are completely independent of each other. We argue that this depends on the research scope and the overall research question.

Table 3.1: Cluster statistics for results from HC (example from Kluge et al. (2020)).

Scenario name	Included projections	Probability (mean)	Impact (mean)	Desirability (mean)
1) Personalized D2D travel	1, 4, 6,10	6.04	5.81	5.46
2) Integrated D2D travel	5, 14	6.29	6.08	5.97
3) Game changer	16	4.53	5.11	4.18

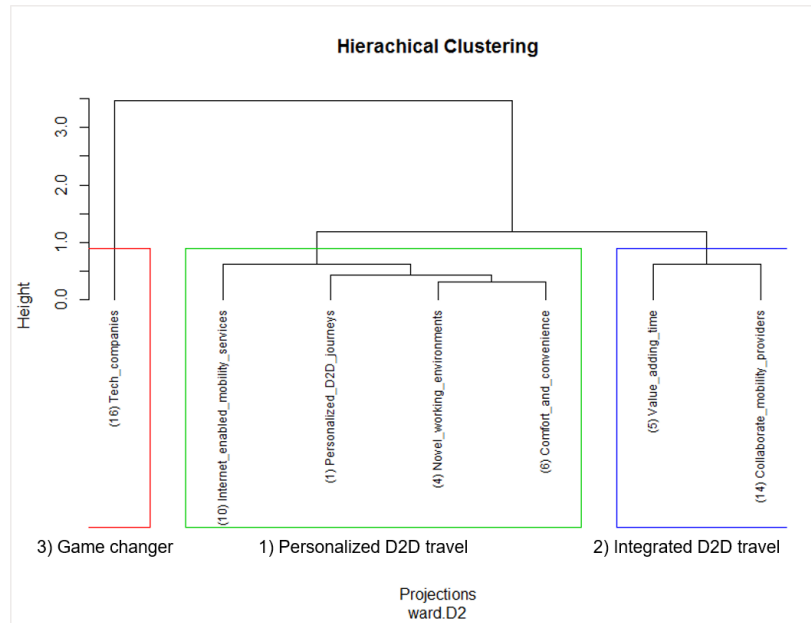


Figure 3.4: Dendrogram of three future scenarios in nested structure for D2D mobility in 2035.

3.5.1 Lessons learned from developing scenarios

- Scenarios help to present research results in a vivid manner and easily to communicate for readers and practitioners. This applies not only to Delphi studies, but to all research incorporating scenario development.
- Applying a cluster analysis provides a systematic and transparent way to build scenarios. It may also exclude the subjective view of the research team, however, the final decision on the clusters and interpretation often follows a more heuristic approach (Tapio 2003). Next to the Delphi-based scenario approach described in this paper, de-bias strategies are also available in this broader context of scenario development in an overview by Schirrmeister et al. (2020).
- Choosing a cluster algorithm and number of clusters is not easy. With regard to the chosen algorithm, Charrad et al.'s majority rule may provide support (Charrad et al. 2014). The R package applies 30 clustering validity indices simultaneously, and makes recommendations based on the number of clusters most frequently mentioned among all indices. This can save time and provides a rigorous basis for cluster analysis and ensuing scenario development.
- Scenarios should be named and described. They might, of course, simply be called 1) probable future developments, 2) possible future developments and 3) alternative future. During the Delphi study, we received the feedback to select individual names to make our results appealing and clear. As described above, comments by panelists may help to describe scenarios. The literature review and expert interviews may also provide support.

3.6 MANAGERIAL INSIGHTS (STEP FIVE)

Scenarios can support organizations in the pre-planning phase, shedding light on the possible future environment of their businesses (Sarpong and Amankwah-Amoah 2015). Deriving managerial insights from final Delphi study results can make them impactful and relevant to practitioners and the industry. We derived managerial implications for different stakeholder groups from our panel, and customized our results for airports, airlines and public transport providers throughout the D2D air travel value chain. In other words, we sought to determine *how the results and developed scenarios would affect the mobility sector and organizations*. As we consider the derivation of managerial insights to be essential, we included this in our research approach.

Future D2D Air Travel in 2035

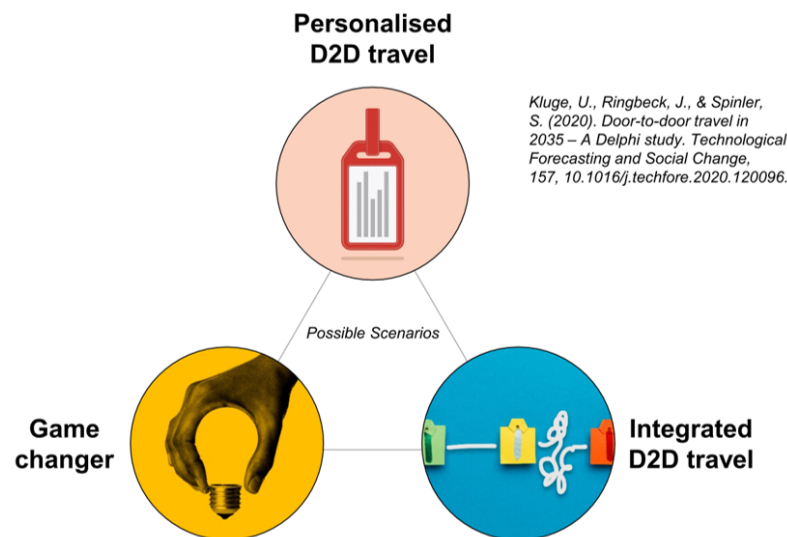


Figure 3.5: Example of the visualization of scenarios (Bauhaus Luftfahrt 2020).

Incentives may be helpful for recruiting panelists, such as social recognition (name people on the panel list), providing a copy of the final research results or offering vouchers⁸. We found that distributing the results was a sufficient incentive for our study. Hence, we prepared a summary of our Delphi study results and distributed this report to all panelists. The summary was short but comprehensive, with references to the original publication. The panelists had professional, mobility-related backgrounds, and their replies indeed confirmed that our study results were useful for their personal work. To present the developed scenarios in a more practical way, we also considered it useful to work with visualizations, which made it easier to understand and represent the scenarios, as depicted in Figure 3.5.

⁸Use of vouchers may introduce limitations or biases and must be discussed at the planning stage.

3.6.1 *Lessons learned from managerial insights*

- Deriving managerial insights highlights the practical relevance of the Delphi study results. To increase their relevance, we tailored our managerial insights to the main stakeholder groups in our study. For instance, through the lens of airlines, how would our Delphi study results affect airline businesses today and in 17 years' time?
- Presentation is important. We learned that presenting our results in a visualization or descriptive figure helped to disseminate our findings beyond the scientific community. Figure 3.5 depicts an example.
- Providing a summary of the Delphi study findings may be an incentive for recruiting panelists. Researchers are advised to prepare a summary and distribute it on completion of the study. Alternatively, the published paper or report may be distributed, although panelists may have little time to appreciate a comprehensive report.

3.6.2 *Method validation*

We regard research methods like the Delphi technique as appropriate for investigating novel topics such as future D2D air travel. The results provide initial insights into possible future developments that would otherwise be difficult to identify. Until the future has become the present, it is impossible to obtain any quantitative data to validate such research. Hence, we highly recommend conducting an a priori literature review to provide a theoretical framework for the development of projections and to increase the rigor of the research. Triangulation of methods can be ensured by using several methods in developing projections.

Our results are highly relevant to both academia and management practice, for example in enabling identification of emerging research areas and supporting the pre-planning process within organizations. However, we do not consider our research results to be useful for enabling theory building. Hence, we believe that further research is necessary for that purpose. As explored in Section "Method details and co-submitted research", the Delphi technique can also be used to address other research questions and current issues, where validation steps might apply. In such context, Delphi studies might be more useful for theory building. However, this is not the scope of this paper.

3.7 REFLECTION AND CONCLUSION

3.7.1 *Reflection on the method*

Although the Delphi technique can be time-consuming, requires much effort, and can be costly, we consider the technique as valuable for several reasons: (1) it allowed us to incorporate the desired D2D air travel, multi-stakeholder scope in the research, (2) we were able to include industry expert knowledge in our study that aims to answer a practical research question and is hence of

high relevance for the industry side, (3) the technique can be combined with other methods, such as with interviews, workshops, scenario development and other methods (as all described above), and (4) we believe it is a universally applicable technique, suitable for students, early-career researchers, and more experience researchers across all disciplines.

Overall, we believe that our Delphi study provides valuable results for the industry by deriving managerial insights at the end of the process. Additionally, the new scope of D2D air travel provides valuable contributions for the academia and policy makers. Recent EU-funded projects focus on intermodal air travel (CAMERA 2019, DATASET2050 2017), thus showing the high practical relevance of this scope. There are, however, some limitations applying the technique. We developed three possible future scenarios but since a few months, the COVID-19-related crisis is affecting the travel and aviation industry heavily. Passengers' demand for air travel dropped for European carriers more than 80% (September 2020 vs. 2019) (IATA 2020b). Nobody can foresee how this crisis will change the aviation industry and D2D travel chains in the long term. We did not include such development in our study as we conducted the research in 2018 with no information on that matter. It could have been included as a game changer scenario; however, one can conclude that there are uncertainties that the Delphi technique cannot capture. We live in an ever-changing environment with technology, society, policies, laws, and other areas changing at a fast pace. One always needs to reflect on the context in which panelists provide their assessments in the Delphi study.

3.7.2 *Conclusion*

In this technical paper, we provide a replicable five-step research process for conducting a two-round Delphi-based scenario study examining the future of D2D air travel in 2035. Lessons learned from applying this framework are provided, including advice for other researchers. We consider the Delphi technique to be a valuable research tool that can be applied in many disciplines and areas of research. It is a technique for answering prospective research questions, but can also be used for other research purposes. Although applied mainly in the fields of healthcare, education and business research, we encourage researchers from other fields to apply the Delphi method.

3.8 INTERIM CONCLUSION OF THE DELPHI STUDY AND OUTLOOK

The results of Chapter 2 shed light on the question: *What could future D2D air travel look like?* In this Delphi-based scenario study on future trends of D2D long-haul travel in 2035 on the European travel market, seven trend hypotheses are confirmed, and three possible future scenarios are developed: (1) personalized D2D travel, (2) integrated D2D travel, and (3) the game changer as the black swan scenario. Chapter 3 delineates the technical details, lessons learned, and a five-step research process, making this Delphi approach replicable for other scholars.

In this research context, the Delphi technique explores an emerging research area and helps our understanding of expert judgments on trend hypotheses. Results provide first indicators of possible future developments but have no claim to absolute and general validity. However, Delphi studies can be combined with research methods to enhance results and generate additional insights (Gerhold et al. 2015). These can use both qualitative and quantitative methods. As seen in Chapter 2, Delphi results can be used for scenario development, such as idea-generation, to increase creativity or provide input from expert judgments (Nowack et al. 2011). Brady (2015) discusses how the Delphi survey can be used to generate practical theory in qualitative research, exemplified with findings from a community-engaged study. Another approach is proposed by Päivärinta et al. (2011) and combines the Delphi technique and Grounded Theory in the Grounded Delphi Method using techniques from both methods to build theory.

Given the organizational view of this dissertation project, findings in Chapter 2 do not provide insights into how TSPs along the travel chain already consider, act upon, or implement these trends. To explore the research objective of this thesis further, results are combined with complementary methods, which will be the focus of the second and third part. To understand trends in-depth and to identify in what way the industry is already acting upon these trends, data science techniques offer novel approaches (George et al. 2014). The following study builds upon results from the Delphi study to cover the aforementioned research gap using text-classification models.

Exploring trends in corporate reports using text classification models¹

4.1 INTRODUCTION

In light of the COVID-19 pandemic and its fundamental impact on air travel, it may become more important than ever to offer bundled and contactless D2D air travel to regain passengers' trust and meet hygiene regulations. In pre-COVID-19 times, air travelers complained (Schmitt and Gollnick 2016) about factors such as lack of comfort (Baumgartner et al. 2016, Sezgen et al. 2019), non-transparent pricing (Budd et al. 2016), long travel times (Ureta et al. 2017) and disruptions (Kim and Park 2016). Many of these pain points affect not just a particular flight segment but all parts of the journey. Exploring the entire D2D travel chain is indispensable to tackling these problems and improving the overall journey experience for air transport passengers. The scope of D2D is of high practical relevance to the industry, and had already been recognized pre-COVID-19 by organizations such as Lufthansa (Lufthansa Innovation Hub 2020c), International Air Transport Association (IATA) (IATA 2020c) and Boston Consulting Group (Wade et al. 2020). D2D solutions may open up business opportunities for TSPs, such as additional revenues and market share from innovative and integrated travel products, and the potential to introduce novel airport access modes, such as UAM, airport car sharing and high-speed transrapid systems. Environmental debates also influence air travel chains, giving rise to flight shaming, less willingness to fly and a concern to reduce carbon dioxide emissions.

Extant studies discuss factors affecting many parts of the D2D air-travel chain (Kluge et al. 2020). To remain competitive, the industry supply side (airlines, airports, airport feeder providers) must understand these factors and respond to novel developments (Wade et al. 2020). Some studies highlight their managerial implications, but none has so far examined whether TSPs act on them. This paper fills this gap by presenting an innovative approach to uncovering the relevance of strategic aspects of the supply side. We ask *to what extent do TSPs consider prevailing factors in their strategic planning and incorporate them into their communications?* To answer this question, we apply two novel text-classification models to textual organizational data drawn from providers covering the five main segments along the D2D air-travel value chain. We determine strategically relevant trends in the dataset that must be accounted for in organizational decision-making. These aspects are represented by seven classes, developed from hypotheses based on a literature review of mobility research.

Text analytics, as part of machine learning, is already used in the industry. A recent survey of 295 German companies reveals that around 46% already apply text analytics (IDG Business Media 2020). Among other metrics, the

¹This chapter is based on Schmalz et al. (2021d): Schmalz, U., Ringbeck, J., Spinler, S., 2021d. Door-to-door air travel: Exploring trends in corporate reports using text classification models. *Technological Forecasting and Social Change* 170, 120865.

Lufthansa Innovation Hub (2019) uses simple keyword frequency counts from annual reports and social media platforms to develop the airline's digital index. Text analytics also has implications for finance and accounting (Loughran and McDonald 2016). Bloomberg Professional Services (2018) uses natural language processing to retrieve valuable company information from unstructured text, such as news articles and social media data, applying the support vector machine (SVM) and the K-nearest neighbors (KKN) algorithm in its text classification model. Insights from the model's results support investment decisions.

This paper is structured as follows. Section 4.2 presents a definition of and trends in D2D air travel, elaborates on previous text analytics studies and highlights this study's contributions. The methodology is described in Section 4.3. Section 4.4 explains the development of the prototype text classification models and their outcomes, which are discussed in depth in Section 4.5. Section 4.6 specifies some limitations of this study, suggests avenues for further research, and draws some conclusions.

4.2 DEFINITION AND PREVIOUS WORK

After defining D2D air travel, this section reviews key trends in this area, presented in terms of seven trend hypotheses, and explores studies that have leveraged textual data.

4.2.1 *Door-to-door air travel*

D2D air travel is defined in this study as the physical movement of passengers from origin to final destination, including all modes of transport, transfer and supporting activities (see Figure 4.1). The study focuses on travel chains that include air transport, so everyday mobility, vacation packages offered by travel agencies and hospitality services are not within its scope. It considers both passengers (demand side) and companies offering mobility products and services (supply side), also known as TSPs.

The D2D air-travel chain consists of five main segments². In developed markets such as Europe, feeder traffic for airport access and egress is covered by public transport, private vehicles and individuals walking or cycling (Budd et al. 2016), as well as by new sharing mobility concepts such as Uber (Young and Farber 2019). These door-to-kerb (D2K)³ and kerb-to-door (K2D) segments are characterized by multi-modal mobility offers, short distances and low speeds (Schmitt and Gollnick 2016). Short-distance transfers within airports provide the interface between feeder traffic and air transport (Schmitt and Gollnick 2016). These are kerb-to-gate (K2G) and gate-to-kerb (G2K) segments. The flight component is operated by airlines in the gate-to-gate (G2G) segment. Passengers on connecting flights may pass through these segments several times. B2B suppliers, such as automotive and aircraft manufacturers, support TSPs. On the horizontal level, digital travel platforms like Google,

²For similar definitions and models, see García-Albertos et al. (2017) and Ureta et al. (2017).

³The kerb refers to the pedestrian area outside the terminal building.

Booking.com and Skyscanner serve as D2D mobility integrators in all five segments (Javornik et al. 2018, Schulz et al. 2018).

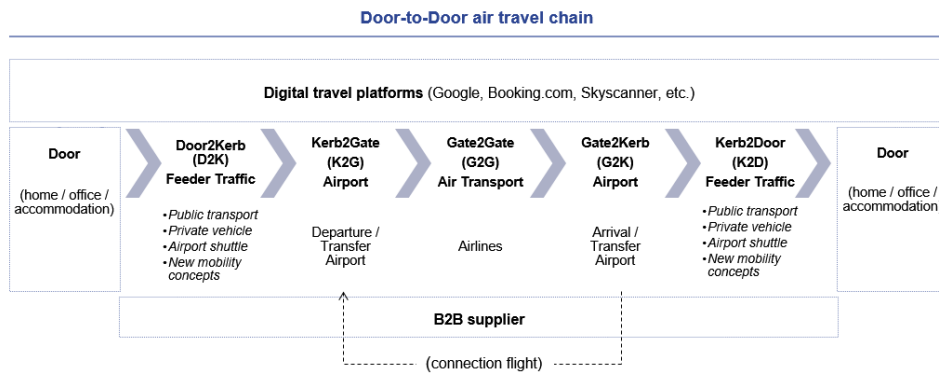


Figure 4.1: TSPs along the D2D air-travel chain (authors' depiction).

D2D travel is often examined in urban mobility studies, but these often neglect D2D air-travel chains. The latter include the air transport leg, which gives rise to increased research complexity for several reasons, including the difficulties of collecting real D2D air-travel-time data from passengers (García-Albertos et al. 2017) and combining travel legs in research activities such as surveys (Susilo et al. 2017). This study adopts a D2D perspective on air travel, focusing on the European market. The analysis covers TSPs operating in each of the five main segments, which together comprise the scope of D2D air travel.

4.2.2 Hypothesis development

In this section, seven key hypotheses are proposed, which are as mutually exclusive and collectively exhaustive (MECE) as possible. These are based on previous literature, including (1) the results of a Delphi study of the future of D2D air travel (Kluge et al. 2020); (2) current demand-side pain points along the D2D travel chain (Baumgartner et al. 2016, Budd et al. 2016, Kim et al. 2016, Monmousseau et al. 2019, Rothfeld et al. 2019, Sezgen et al. 2019, Ureta et al. 2017); and (3) disruptive trends in the aviation and overall mobility sector, such as the climate debate and exogenous shocks. As in other studies, scientific publications are considered as sources identifying the latest developments and most pressing challenges (Li et al. 2019). The trends characterized by the hypotheses are already affecting all or parts of the D2D air-travel chain. Hence, they must be understood and integrated into mobility service providers' decision-making processes in order to offer integrated and successful D2D solutions. In other words, these hypotheses address the question: *what factors are important for creating successful D2D products and services?*

1. Personalization

Different passenger segments have differing needs (Kluge et al. 2018b). Different generations, such as Millennials or young travelers (Garikapati et al. 2016) and the elderly (Siren and Haustein 2013, 2015), have increasingly differentiated and fragmented customer needs that mobility service providers along the

travel chain must be able to fulfill. We argue that it is essential to understand passenger types and provide personalized options to cater to all passengers' needs. The personalization of travel (and other industries) has already begun and is predicted to shape the future of D2D air travel (Kluge et al. 2020). This applies to ancillary products, such as pre-travel information, on-board services and in-flight entertainment, as well as to the core travel product itself. Based on these arguments, the first hypothesis (H) is:

H1: Door-to-door air travel chains are highly personalized.

2. Passenger data

Providing enhanced, digital D2D travel services requires the use of passenger data. Airlines already possess large amounts of passenger-related information, such as demographic information, flight class (premium vs. business), trip purpose and financial information (Javornik et al. 2018). It is predicted that such data will be leveraged to improve services along the air-travel value chain (Wade et al. 2020). Studies show that passengers are willing to share personal data if they receive benefits in return. For instance, 80% of time spent in the K2G segment is buffer time (Ureta et al. 2017), which might be reduced by improving airport processes and reducing waiting times (Monmousseau et al. 2019). Two-thirds of passengers would share more personal data to support faster airport processes (IATA 2019). Digitizing the travel chain and leveraging passengers' data may support the provision of integrated and digital D2D travel solutions, and help to predict future needs. This leads to the second hypothesis:

H2: Passengers' data are leveraged to improve the digital travel experience and offer enhanced services along the D2D air-travel chain.

3. Establishing partnerships

Mobility service providers operate within their own travel segments and cannot control the services of other segments. To provide integrated and bundled services, partnerships and collaborations with other providers along the D2D air-travel value chain are essential. Examples include Rail&Fly (Lufthansa 2019) and D2D luggage delivery services (Luggage Free 2020). We argue that such collaborations may create a competitive advantage, as already proven in early studies of integrated air-bus products (Merkert and Beck 2020). TSPs can become real D2D mobility providers. Collaborations with tech companies may enhance offers along the travel chain (Kluge et al. 2018a), as they have the necessary infrastructure and can provide customized content on personal devices, travel recommendations and other services. Hence, the third hypothesis is:

H3: Establishing partnerships with other mobility service providers and tech companies is essential for offering bundled D2D solutions.

4. Environmentally friendly air transport

In light of current environmental debates and climate-related challenges, mobility must urgently change, for instance by decarbonizing transport, introducing carbon-offsetting programs and using renewable aviation fuels (RAF). Reg-

ulations and political agendas such as Flightpath2050 (European Commission 2011), the EU Emissions Trading System (European Commission 2020a) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSA) (ICAO 2020) are pushing airlines to explore alternatives to kerosene, including renewable drop-in fuels, hydrogen and electricity (Bauen et al. 2020). Programs fostering carbon reduction also apply to airports, such as the Airport Carbon Accreditation (ACA) scheme (ACI EUROPE 2009). Environmental awareness and related behavioral changes appear to be increasing among the European population (European Commission 2019b), for example with regard to their willingness to reduce air travel, pay for carbon-offsetting and use environmentally friendly substitutes for flights (European Investment Fund 2020). TSPs need to react to this emerging trend on the demand side and create sustainable, D2D transport solutions, not only to remain competitive, but also to contribute to preserving the planet. The fourth hypothesis is as follows:

H4: Offering environmentally friendly air transport solutions and related transport products is indispensable.

5. Airport feeders

The time taken to access and egress airports (D2K and K2D segments) needs to be reduced significantly. Using Google Maps data for 22 major European airports, Rothfeld et al. (2019) show that driving a private vehicle is still faster than using public transport. Alternative transport modes that bypass traffic jams (like subways) might also save travel time (Monmousseau et al. 2019). In addition to conventional airport feeders (Budd et al. 2016), some studies explore new transport concepts as alternative modes of D2D connections in Europe, such as on-demand air taxis (Sun et al. 2018)⁴. In addition to potentially autonomous air taxi solutions, other mobility concepts have already entered the market, such as ride hailing and car-sharing, which are further changing passengers' travel needs and mobility patterns (Bardhi and Eckhardt 2012, Young and Farber 2019). Enhancing the quality of airport feeds with regard to time and available modes improves the entire D2D travel experience. Hence, the next hypothesis is:

H5: Novel mobility concepts improve airport feeder traffic.

6. Disruption management

Over 55% of air passengers faced travel disruption in 2019 (IATA 2019). This may occur when using airport feeder services, so many passengers arrive at the airport early to allow a time buffer, which accounts for up to 80% of time spent at airports (Ureta et al. 2017). Flight delays are another potential source of disruption, and may lead to negative emotions for air travelers (Kim et al.

⁴A recent study (McKinsey & Company 2021) predicts a general shift in the European market away from private vehicles towards new modes of transport until 2030. Business travelers and high-net-worth individuals are predicted to be first movers for air taxis (Kluge et al. 2019) (Kluge is the maiden name, and the author is now called Schmalz). Although explored in the extant literature, we do not consider on-demand air taxis as a form of mass transport for airport feeder traffic, and hence exclude these and similar companies from this analysis.

2016). Another disrupter is luggage delays (Sezgen et al. 2019). Delayed airport feeds, late flights and delayed luggage may impact negatively on onward connections and bookings in later travel segments. Disruption management entails avoiding disruptions to one's own services and, if necessary, acting upon them, for example through automatic rebookings, real-time flight status, alerts and luggage information (IATA 2019). This may significantly improve passengers' experience, saving them time and reducing stress. Hence, the sixth hypothesis is:

H6: Managing disruptions (delays and operations) along the D2D air-travel chain improves the passenger experience.

7. Exogenous shocks

Exogenous shocks are defined here as events that seriously affect the air transport system, including D2D air travel. Terrorist attacks and pandemics are examples. In recent years, terrorist attacks have occurred around the world (Esri and Peacetechnology 2020), impacting on D2D air travel. For example, following the attacks of September 11, 2001 in the United States (US), global air transport operations changed fundamentally with regard to airport security procedures and luggage screening (Blalock et al. 2007, TSA 30.12.2002). A business travel stress model shows that personal safety, before and during trips, may also be a stressor at the individual passenger level, leading to fear and anxiety (Ivancevich et al. 2003). The long-term consequences of the current COVID-19 crisis for the transport and aviation industry are already obvious (OAG 2020, Pearce 14.4.2020, Škare et al. 2020). Such incidents may impact not only on demand for air travel, but also on passenger requirements and travel procedures, such as airport health screening during the Ebola epidemic (Gold et al. 2019). Passengers' concerns about picking up infections during travel were identified some time ago (Gustafson 2014). TSPs may be required to introduce additional health screening (Gold et al. 2019) and hygiene measures in cabins (IATA 2020a). Exogenous shocks require mobility service providers to be resilient (Linden 2021) and hence constantly adapt to new health and safety regulations, leading to the final hypothesis:

H7: Exogenous shocks (e.g., terrorist attacks and pandemics) require mobility service providers to constantly adapt towards new health and security issues.

Table 4.1 summarizes all the hypotheses and the keywords used to describe them. Both the hypotheses and the keywords were pre-tested with two aviation experts. The most frequently-used keywords were included, avoiding the provision of more detail than necessary for the models. The keywords contain essential information, and examples were retrieved from the trend hypotheses and company names, such as potential partners, start-ups and associations (see Table 4.3 and Table B.6 for details). In the analysis, airports, airlines, public transport and railway companies were also included as keywords. These are listed in the Appendix (see Table B.1, Table B.2 and Table B.3). Given the definition of D2D air travel in Section 4.2.1, the travel segments to which the hypotheses are most applicable are also indicated (see Seg.).

Table 4.1: Hypotheses and related keywords.

Seg.	Hypotheses	Metrics (Keywords)
D2D	Personalization (H1)	Customisation, customisation, flexibility, individualisation, Mobility as a Service (MaaS), on-demand, pattern recognition, passenger, personalisation, preference, passenger segment, passenger need, passenger requirement, targeted advertising
D2D	Passenger data (H2)	Automated self-boarding, blockchain, biometric identity, customer data, chatbot, data, data mining, digitalisation, digital element, digital experience, digital service, digital journey, home-printed tag, mixed reality, mobile service, passenger data, predictive analytics, passenger mobile app, passenger experience, robot, autonomous machine, SITA, self-service, tracking, virtual agent
D2D	Establishing partnerships (H3)	Add-on product, Amazon, Artificial Intelligence (AI), Airbnb, air-rail connection, booking.com, bundled services, C Teleport, Culture Trip, co-modal, collaboration, cooperation, Dohop, Dreamlines, door-to-door, (D2D), Evaneos, Flightsayer (Lumo), GIVT, GetYourGuide, Google, HomeToGo, integrated service, IATA, integrated solution, interface, intermodal, interoperability, LuckyTrip, Maas Global, multimodal, Mobian, Netflix, nodes, Omio, partnership, Resolver, Skyscanner, Selina, Secret Escapes, TravelPerk, Tiqets, wemovo, WeSki, (airline, airport, railway, bus, public transport) (customized keywords depending on TSP: airline, airport, railway, bus, public transport providers)
K2G, G2G, G2K	Environmentally friendly air transport (H4)	Alternative fuel, ACA, carbon footprint, carbon offsetting, (carbon) compensation, CORSIA, decarbonisation, eco-friendly, ETS, electrification, emission, emission trading system, environment-friendly, environmental awareness, flight shame, Fridays for Future, green mobility, Gevo, Greenpeace, hydrogen, Neste, renewable fuel, renewable diesel, renewable aviation fuel, renewable drop-in kerosene alternative, SG Preston, Swedish Biofuels, sustainable energy system, sustainable aviation fuel
D2K, K2D	Airport feeders (H5)	Access, egress, accessibility, autonomous driving, BeeRides, Bipi, BlaBlaCar, Bolt, Blue Label, Car Sharing, car&away, Cabify, Cluno, feed, Free Now, FlixBus, innovation, last mile, Lyft, mobility concept, moovel, MyTaxi, novel / emerging mobility concept, on-demand private shuttle, pooling, ride hailing, RideLink, SeaBubbles, seamless, shared mobility, Sono Motors, Taxizairport, transrapid, Uber, Viruo, Welcome Pickups
D2D	Disruption management (H6)	Automatic rebooking, alert, cascading effect, customer care, disturbance, disruption, disruption management, journey re-configuration, network congestion management, push notifications, real time status, service delay, travel assistant, travel flow, travel itinerary
D2D	Exogenous shocks (H7)	Crisis, exogenous shock, epidemic, hygiene measures, health on board, health screening, luggage screening, monitoring, passenger safety measurement, pandemic, resilience, reaction, recover, regulation, supply shock, security, technological shock, terrorist attack, terrorism, WHO

4.2.3 Using textual data for transportation research

Analysis of textual data has several advantages, including cost efficiency, the widespread availability of publicly accessible data from the Internet (Rose and Lennerholt 2017), and the ability to analyze large volumes of documents (Kadhim 2019). Text analytics, as part of machine learning, is an interdisciplinary research method applicable to textual data, grounded in the theory of content analysis. It is applied to unstructured data such as blogs and technical documents (Anandarajan et al. 2019), and semi-structured data such as social media content (Kinra et al. 2019). The Internet is the largest repository of research data (Rose and Lennerholt 2017), although corporate data is increasingly being used in the industry (Bloomberg Professional Services 2018, IDG Business Media 2020).

Transportation research is increasingly using such data resources, owing to recent methodological advances and the variety of textual resources available (Kinra et al. 2019). This may reveal various insights, depending on the technique applied and the data resources available. This section provides an overview of how textual data can be used in transportation research, with a focus on aviation, as summarized in Table 4.2.

Researchers are applying text analytics techniques to user-generated online content, such as online customer reviews (OCRs). Sezgen et al. (2019) explore the drivers of passengers' satisfaction with airline products and services using latent Semantic allocation (LSA) of passengers' reviews retrieved from the travel platform TripAdvisor. Other studies follow a similar approach, using OCRs as data samples for text analytics (Korfiatis et al. 2019, Lucini et al. 2020)⁵. Textual data can also be used for market segmentation purposes. For example, Punel and Ermagun (2018) apply cluster analysis to Twitter data to explore airline passenger segments. Kim et al. (2017) provide a comprehensive overview of OCR studies in the broader context of tourism and hospitality, and apply sentiment analysis to online reviews by travelers visiting Paris. Kuhn (2018) applies the structural topic model (STM) technique to aviation safety reports to identify trends and topics in that field, and Das et al. (2020) use STM and latent Dirichlet allocation (LDA) to detect 20 key research topics in data drawn from transport-related research published in the *Transportation Research Record: Journal of the Transportation Research Board*.

Organizational textual data have also proven to be suited to text analytics. Law and Breznik (2018) apply content analysis and network analysis to airline mission statements to identify airlines' embedded values, and Lin et al. (2018) use airlines' mission statements to develop a framework of mission statement components. Seo (2020) detects shared values between airline alliance members by analyzing and comparing the content of 61 airlines' mission statements. Annual reports have also been used as a data source. Kumar and Rao (2019) develop a performance evaluation instrument using information from airlines' annual reports and financial statements. Secondary information on airlines can be collected by combining annual reports with sustainability and corporate

⁵The review of OC Rs studies is not exhausted, Lucini et al. (2020) discuss most recent work.

social responsibility (CSR) reports, as in McLachlan et al. (2018) who study the impact of environmental concerns on passengers' airline selection.

Table 4.2: Text analytics in transportation research.

Author(s) (Year)	Study Scope	Used Data	Methodology
Sezgen et al. (2019)	Investigation of key drivers for airline passenger satisfaction	key OCRs	latent Semantic allocation (LSA) (text mining and categorization)
Korfiatis et al. (2019)	Making airline service quality measurable in its various dimensions	OCRs	STM (extension to latent Dirichlet allocation (LDA) method; allows to run correlations among developed topics)
Lucini et al. (2020)	Measuring airline customer satisfaction	OCRs	LDA
Punel and Ermagun (2018)	Deriving passenger segments	Twitter data	cluster analysis
Kim et al. (2017)	Measuring tourists' perception on travel experience	Online traveler reviews	sentiment analysis
Kuhn (2018)	Detection of known and unknown trends and topics	Aviation safety reports	STM
Das et al. (2020)	Deriving main underlying research topics	Transport-related journal papers	LDA & STM
Lin et al. (2018)	Identifying key components of airline mission statements	Mission statements	content analysis
Law and Breznik (2018)	Detection of embedded key values	Mission statements	content analysis, network analysis
Seo (2020)	Detection of shared values within airline alliances	Mission statements	content analysis
Kumar and Rao (2019)	Development of a performance measuring metric for airlines	Annual and business reports	various statistical analyses
McLachlan et al. (2018)	Assessing the environmental impact on customers' decision-making	Annual, sustainability and CSR reports	consumer questionnaire

Textual analyses of OCRs have become dominant in research and can be used as a resource for organizational decision-making, supplementing traditional customer surveys. OCR studies can use large sample sizes and can be updated daily, although their application presents some challenges (Roberts et al. 2014, Silge and Robinson 2017). For example, funding is needed to retrieve a critical amount of historical data for research purposes (Kinra et al. 2019). Internal corporate textual data, such as emails, intranets and wikis, are insightful but not publicly accessible (Kinra et al. 2019), whereas corporate mission statements are publicly disclosed, conveying corporate values and visions.

However, mission statements were considered too high-level to achieve the research objective of this study, which used annual reports and, if available and not already included, sustainability reports as data sources.

4.2.4 *Contribution to the literature and practical implications*

Previous work has explored research questions using text analytics techniques, and has focused on parts of the D2D journey. Given the high practical relevance of intermodal, D2D air-travel solutions, this study focuses on the entire D2D air-travel value chain. It makes several contributions to the literature and has practical implications for the industry. First, it investigates a novel research context in its entire D2D scope, including all TSPs along the travel chain. Second, it conducts trend analysis, adopting an innovative approach to assess systematically whether companies consider and communicate key hypotheses and trends, using real-world data. Third, a trend dictionary is built and a text classification model developed, and this learning can be applied to other reports and Big Data, increasing productivity and saving time and other costs. Finally, the study applies text classification models in a novel research setting, and expands the field of application of text analytics and machine learning models.

4.2.5 *Expected results*

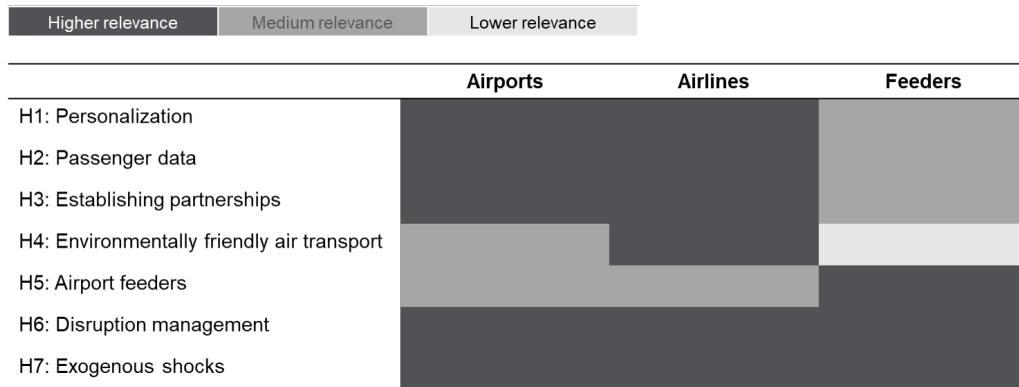


Figure 4.2: Stakeholder analyses: Expected results at TSP level, from weak (light gray) to strong (dark gray) effects.

This review of D2D air travel indicates that most topics apply more to airlines and airports than to feeder traffic providers. D2D travel is relevant to all customers of airlines and airports, but to only a fraction of feeder traffic providers’ customers. Feeder traffic providers also provide public transport for urban passengers, which accounts for a large part of their operations. Therefore, we expect most hypotheses to be more relevant to airports and airlines, as all of their customers need to access the airport and leave for their final destinations. Three percent of the EU’s greenhouse gas emissions are generated by the aviation sector (European Commission 2020a), which also generates other emissions (Lee et al. 2020). This might be reduced by, for instance, switching to RAFs, although airports must also provide the required infrastructure. As

airlines and airports are making the biggest efforts to achieve environmentally friendly transport, H₄ (Environmentally friendly air transport) focuses specifically on the K₂G, G₂G and G₂K segments. Hence, we expect this topic to be of greater relevance in airlines' and airports' communications, with an even stronger focus in airlines' textual data. Improvements to airport feeder traffic (H₅) affect mainly the D₂K and K₂D segments; hence, we expect this hypothesis to be particularly relevant in documents from feeder traffic providers. H₆ (Disruption management) and H₇ (Exogenous shocks) apply to all three providers equally. Overall, we expect higher results for airlines and airports, and lower results for the feeder sub-sample (see Figure 4.2).

4.3 METHODOLOGY

Using text classification models, this study explores whether TSPs along the D₂D air-travel chain consider key trends and findings from research to be strategically relevant, and hence include them in their communications. This section elaborates on the methodological approach and data preparation.

4.3.1 Research objectives and approach

For the purpose of this study, text classification models were built to analyze unstructured textual data to examine the relevance of the identified trends. In these models, pre-defined hypotheses, described by keywords and later by training texts, were assigned to corporate textual data, allowing documents to be allocated to predefined classes (supervised learning) (Grimmer and Brandon 2013, Kadhim 2019). These a priori defined classes were developed in the form of hypotheses (see Section 4.2.2) following a deductive approach (Welbers et al. 2017). The study followed a five-step approach (see Figure 4.3), adapted from Rose and Lennerholt (2017) and Mirończuk and Protasiewicz (2018).

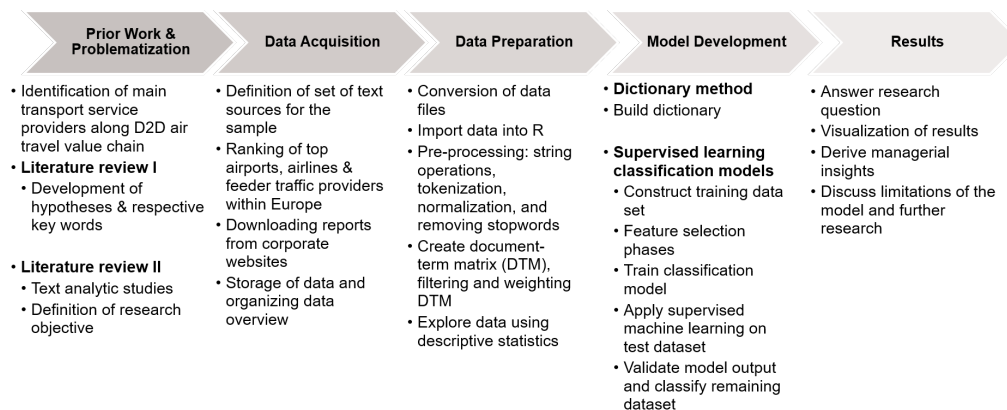


Figure 4.3: Development of classification models: five-step approach (adapted from Rose and Lennerholt (2017) and Mirończuk and Protasiewicz (2018)).

4.3.2 Data acquisition

Corporate textual data were used as data sources, the successful combination of which has been proven in previous studies (McLachlan et al. 2018). Annual reports are publicly disclosed, published yearly and retrievable from corporate websites. In addition to financial disclosures, they contain non-financial information (Esendemirli 2014) on strategy, marketing, and research and development, making this published content strategically important. If not already contained within annual reports, any available sustainability reports, and documents with similar sustainability-related content such as CSR reports, were included for analysis. To create the desired D2D air travel scope, data from airports, airlines and feeder traffic providers were included in the sample. The largest European airlines and airports were taken from the Official Airline Guide (OAG 2018). Airlines that were part of an alliance were considered individually. Airport feeder traffic providers operating in the most highly populated urban areas (by total number of inhabitants) in Europe (Eurostat 19.3.2020) were researched manually. Table 4.3 lists the databases used to develop the rankings, and other sources used to detect keywords (Crunchbase 2020, Lufthansa Innovation Hub 2020a,b, Mordor Intelligence 2020).

Table 4.3: Databases used in the analysis.

Seg.	Source Name	Data Extracted	Year
D2K, K2D	EUROSTAT	Top feeder traffic providers (public transport providers): extracted manually for top 20 European urban areas by inhabitants, including cities and commuting zones	2017
K2G, G2K	OAG	Top airports: largest European airports (by total planned seat capacity, for both arrivals and departures)	2018
G2G	OAG	Top airlines: largest European airlines (by total planned seat capacity)	2018
G2G	Mordor Intelligence	Top five players in renewable aviation fuels market (used as keywords)	2020
D2D	Crunchbase	Top transport start-ups by estimated revenue range (used as keywords)	2020
D2D	Lufthansa Innovation Hub	Europe's 20 top-funded travel and mobility tech startups and corporate venture capital investments by European carriers, by total number of investments (used as keywords)	2020

Using these rankings, a data overview table was created, and the top airlines, airports and feeder traffic providers were researched. The final sample contained data from 71 mobility service providers along the D2D air-travel value chain, comprising 23 airlines, 22 airports and 26 feeder traffic providers. Several transport providers belonged to a single group, and are hence presented in group reports, such as the International Airlines Group (IAG), Aéroports de Paris (ADP) Group and Deutsche Bahn (DB). As the entire group reports were analyzed, the sample contained additional transport providers that were part of these groups but not part of the sample. Hence, the sample size was

actually larger. The 71 TSPs in the sample were represented by 47 individual annual reports (or documents with similar content, such as company presentations and activity reports) and 27 sustainability reports (or documents with similar content) (see Table 4.4). These were downloaded manually from corporate websites in PDF format in English in April 2020. Detailed lists of the sample are presented in the Appendix⁶. The annual reports were merged with any sustainability-related reports for the same company or group. Acquiring annual reports from mobility providers' corporate websites has proven successful in previous research (Kumar and Rao 2019). The base year was mostly 2018 or 2019, depending on availability⁷. Sustainability-related reports are not published yearly and might therefore be older.

Table 4.4: Overview of data sources.

TSPs	Companies in Sample	No. of Annual Reports	No. of Sustainability Reports
Feeders	26	15	8
Airports	22	18	9
Airlines	23	14	10
Sum	71	47	27
Object of analysis	74 reports merged to 52 documents (representing 71 TSPs)		

The airline sample represented 69% of the total seats offered to and from Europe by European airlines, including both LCCs and Full-Service Network Carriers (FSNCs). The airport sample represented 40% of total seats for departures and arrivals at European airports (OAG 2018). If reports were unavailable (e.g., non-functioning url), were not translated into English, or were read-only, the company was excluded from the sample and the next entity on the list was used until a sample size of at least 40% market coverage in Europe was reached. Such sample sizes are considered to provide insightful results. The dataset can be considered to be 'Small Data' (vs. Big Data). Small Data may also produce valid and insightful findings, while reducing costs and resources (Faraway and Augustin 2018). This study aimed to conduct analysis at an aggregated TSP level. As a sufficient sample had already been gathered at a market coverage of 40%, additional data would have not improved the findings, but would have incurred additional expense.

4.3.3 Data preparation

The raw data were uploaded into R and saved in corpus format, a collection of associated texts that is easy to manage (Benoit 2018). Separate corpora were built, representing airport data (N = 18), airline data (N = 18), feeder data (N = 16) and the entire sample (N = 52). Raw data must be reduced in volume and complexity, manipulated and pre-processed to make them usable for learning methods. To keep the data volume low, all PDFs were converted into plain.txt

⁶See Table B.7, Table B.8, Table B.9, Table B.10, Table B.11 and Table B.12.

⁷For some companies, the financial years ends in March.

format and encoded into UTF-8 standard, as recommended by Grimmer and Brandon (2013) and Welbers et al. (2017) and as required for application of the *quanteda* R package (Benoit et al. 2018).

Documents contain noise, such as unnecessary stop words and special characters (Mirończuk and Protasiewicz 2018, Welbers et al. 2017). These were removed during the data preparation, following Welbers et al. (2017) five-step guideline. This process comprised: (1) importation of the textual data into R as raw text corpora, allowing analysis of the data at a document level; (2) string operations; (3) pre-processing of the data, including tokenization, normalization and stemming, and removing stop words using the default list in the *stopwords* package in R (Benoit et al. 2020) and the authors' customized list⁸; (4) creating a DTM using the *quanteda* package (version 2.1.2), which also included some mentioned data preparation steps (Benoit 2018); and (5) filtering and weighting the DTM. Descriptive statistics were produced to explore the data, such as filtering out the top features in the sample and sub-samples, and creating word clouds (see Figure 4.4).

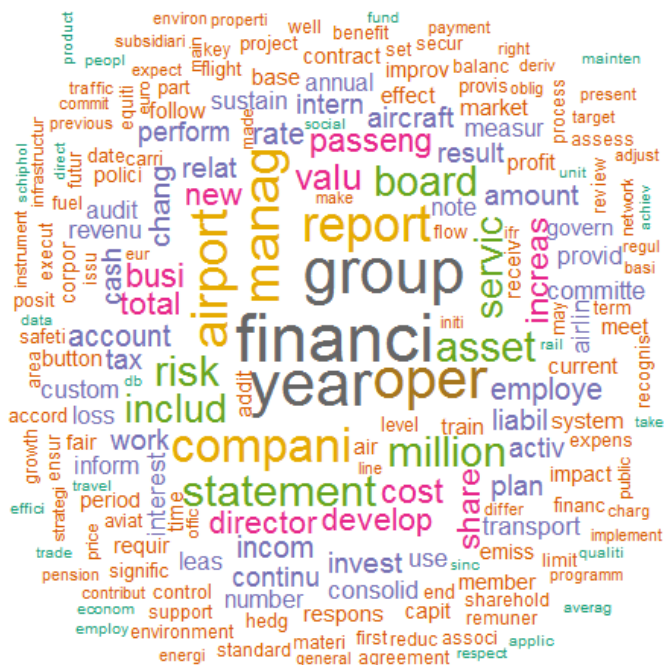


Figure 4.4: Word cloud for top 200 words in entire sample (min. term frequency 1,654).

The raw text corpora differed considerably (see Figure 4.5). The airport data comprised a much higher number of tokens, although conclusions cannot be drawn about the content. After pre-processing the data, this imbalance disappeared⁹.

⁸*Lemmatization* was also considered to improve the results, but according to Welbers et al. (2017), stemming is often sufficient in the English language. Words with similar meanings were included.

⁹The total numbers of tokens were 615,205 for the airport sample, 633,005 for the airline sample and 461,388 for the feeder sample.

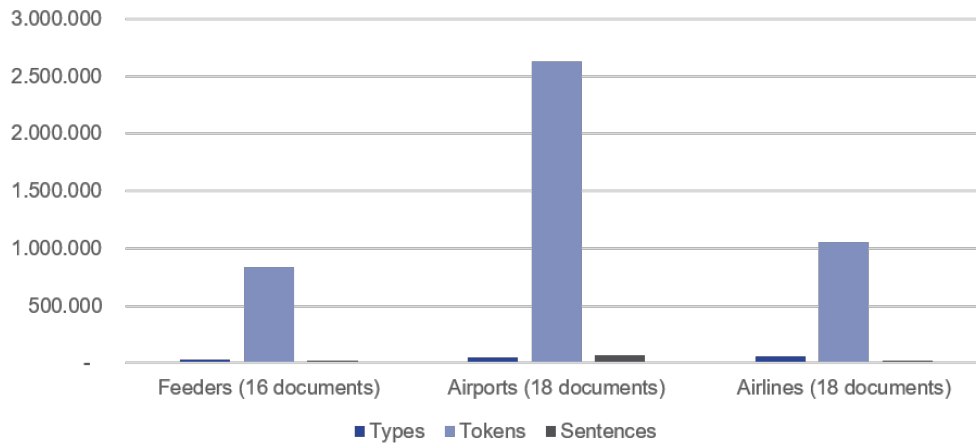


Figure 4.5: Overview of raw data (before pre-processing).

4.4 DEVELOPMENT OF CLASSIFICATION MODELS

The classification models for this study were developed in a multi-labeled setting (as opposed to multi-class classification (Sokolova and Lapalme 2009)). Hence, each document might belong to more than one pre-defined class. As described above, the seven classes for the text classification problem were: 1) Personalization, 2) Passenger data, 3) Establishing partnerships, 4) Environmentally friendly air transport, 5) Airport feeders, 6) Disruption management, and 7) Exogenous shocks. Several approaches are available for classifying documents into multiple categories that are known a priori. Two were applied and compared in this study: dictionaries, and supervised learning classification models (Grimmer and Brandon 2013).

4.4.1 Dictionary-based classification model

4.4.1.1 Building the dictionary

Dictionary analysis counts the frequency of keywords in a sample (Watanabe and Zhou 2020). In this study, a dictionary was developed based on the seven hypotheses (hence seven classes) and the knowledge-based keywords identified in the literature review (see Section 4.2.2), using the *quanteda* dictionary function (Benoit et al. 2018). Each term was used only once for each hypothesis. A basic dictionary of 225 entries was built. Each TSP was also tested for 127 customized keywords¹⁰, leading to an average dictionary of 352 keywords. The keywords were stemmed using the value type *glob* style.

The data sample varied in terms of token volume per document and number of documents per sub-sample. To correct this imbalance, the dictionary results were weighted to calculate the relative frequency (see Equation 4.1). For each document, the number of hits per class was divided by the total number

¹⁰The keyword list for H3 included additional airlines, airports and feeder traffic providers' names, which were applied selectively, leading to three sub-dictionaries for airports, airlines and feeder traffic text corpora. The basic dictionary is shown in the Appendix in Table B.5.

of tokens in each document. The sum of all documents was then divided by the total number of documents (N) in the respective sub-sample (airlines, airports or feeder traffic providers). Relative dictionary weightings have also been applied in previous studies as described by Watanabe and Zhou (2020).

$$\text{Relative frequency (per class)} = 100 \times \left(\frac{\sum_{i=1}^N \frac{\text{hits in document}}{\text{tokens in document}}}{N} \right) [\%] \quad (4.1)$$

where:

i = document's number in subsample

N = amount of all documents in subsample

4.4.1.2 Interim results

After applying the dictionary, the interim results (see Figure 4.6) gave an early indication of which hypotheses (keywords) might occur in the TSPs' documents, and which might be less represented. The dictionary matched around 7% of the textual data in the sample. The results indicated that H1 (Personalization) and H4 (Environmentally friendly air transport) exhibited the highest matches. H2 (Passenger data), H5 (Airport feeders), H6 (Disruption management) and H7 (Exogenous shocks) were each represented with similar frequency counts in the data, suggesting that these four themes might be similarly relevant to TSPs' communications efforts. H3 (Establishing partnerships) was least represented. However, a strong effect appeared after the customized keywords were applied at the TSP level in each dedicated sub-dictionary. Without testing for other TSPs' names, H3 matched 4,499 data points (vs. 14,173). Hence, the dictionary classifier was very sensitive to providers' names. The results also provided frequency counts for each TSP level.

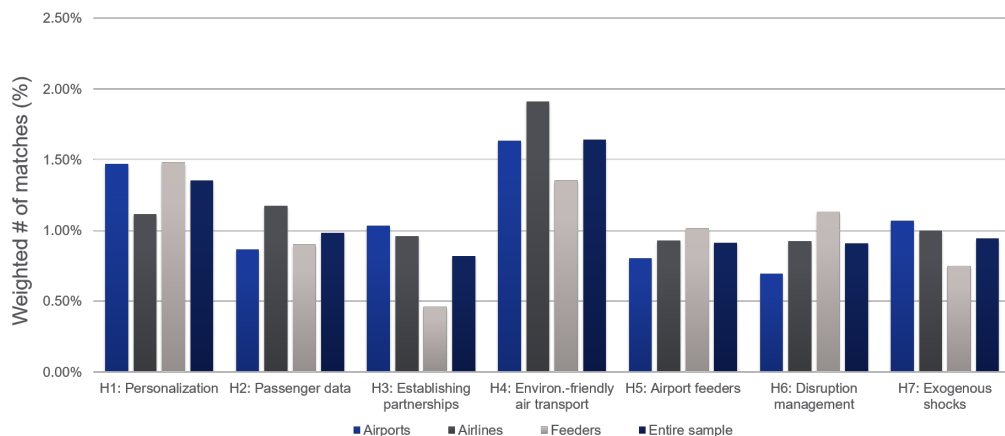


Figure 4.6: Weighted results of applying the dictionary method.

Terms that seemed to be too general in meaning (e.g., *journey*, *travel**, *mobi**, *produc**, *system**, *aviat**, *effect**, *mana**, *technol*) were excluded before applying the dictionary. Exploration of individual entries in the interim results revealed that some terms matched with many data points, such as *passeng** (passenger) (H1), *servic** (service) (H1), *board* (board) (H2), *integr** (integration) (H3),

*sustain** (sustainability) (H4), *energi** (energy) (H4), *share** (sharing) (H5), and *regul** (regulations) (H7). All of these also seemed quite general, making it difficult to generate a high discrimination value for the respective hypothesis.

4.4.1.3 *Validation*

One of Grimmer and Brandon's (2013) four main principles of quantitative text analyses is the need to validate the results. For instance, errors may occur when applying dictionaries that are too generic or keywords developed in other contexts or outside the domain in focus. Validation was carried out by pre-testing the keywords and hypotheses outlined in Section 4.2.2 on two mobility researchers who were not involved in the study. As the dictionary was also based on scientific publications and databases (Table 4.3), a robust foundation was built using sources from a comparable domain to the data sample. Hence, errors due to applying a generic dictionary were avoided. The interim results also showed that around 7% of terms occurred in the data, indicating the relevance of the selected keywords. However, some terms showed high ambiguity as their meanings were general. These generated many more matches than the others. Furthermore, the dictionary method does not allow the retrieval of additional keywords to improve the analysis.

Overall, the dictionary answered the research question simply but efficiently. The task of counting the frequency of keywords was conducted using the dictionary function, which would have been costly to conduct by manually coding all reports by hand while ensuring intercoder reliability. However, this approach has some limitations, as described above. The next section explains the complementary analysis conducted to explore the data further, beyond the purely knowledge-based keywords from the dictionary classifier. The supervised learning approach enabled us to make class predictions, rather than looking only at frequency counts.

4.4.2 *Supervised learning*

4.4.2.1 *Approach*

A supervised learning model was developed for multi-labeled classification (Figure 4.7). Three basic steps adapted from Grimmer and Brandon (2013) were followed: (1) construct the training set, select features and train the model; (2) apply supervised machine learning to the test (validation) dataset; and (3) validate the model's output and classify the remaining dataset.

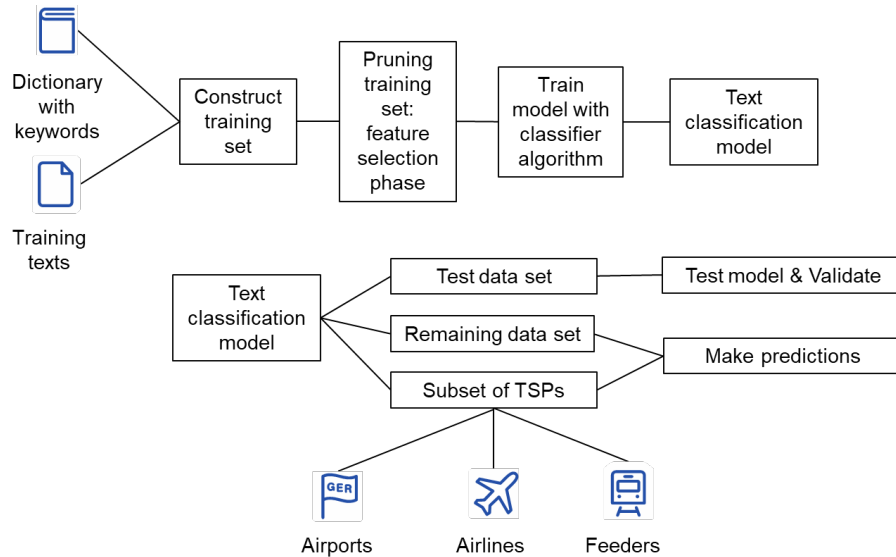


Figure 4.7: Supervised learning model for text classification (authors' depiction).

4.4.2.2 Construction of a training dataset and selection of features

Diverse textual sources were used to train the model and transform the training texts into additional features as inputs for the predictions. As the initial data sample was small, new hand-labeled texts outside the sample were used to construct the training set for each class, such as the keywords discussed in Section 4.2.2 and other related texts. In order to overcome the limitations of the dictionary method, domain-specific (real-world) textual data from corporate sources were leveraged, such as Emirates (2019), Geneva Airport (2018) and ÖBB (2019)¹¹. Not all classes seemed to be well represented in real-world corporate texts, which was another reason for conducting this study. Hence, reports and scientific papers were added, including Li et al. (2019) and Wenzel et al. (2021), as well as reports such as those published by SITA (2019) and accenture (2018) (see Table B.13 for an overview of training dataset).

To avoid data bias, the training texts were evenly balanced between the seven classes. Each class was represented by between 1,100 and 1,500 unique tokens (raw data after pre-processing). Including additional training text and extracting features helped to detect more relevant keywords and exclude human bias from the knowledge-based keyword selection. The training dataset was pre-processed using *1-gram*. To reduce noise and irrelevant words and to avoid overfitting, the training texts were trimmed in the feature selection phase using different term frequencies (minimum term frequencies of 10, 15 and 20). As shown in Figure 4.8, the number of features decreased with higher term frequencies. The training texts were pruned to achieve a minimum term frequency of 20. A higher number would have resulted in fewer keywords than in the dictionary classifier, and would have been counterproductive for leveraging additional features. Moreover, the curve stagnated after the minimum term frequency of 20. The results were compared in the validation phase.

¹¹All not part of the sample.

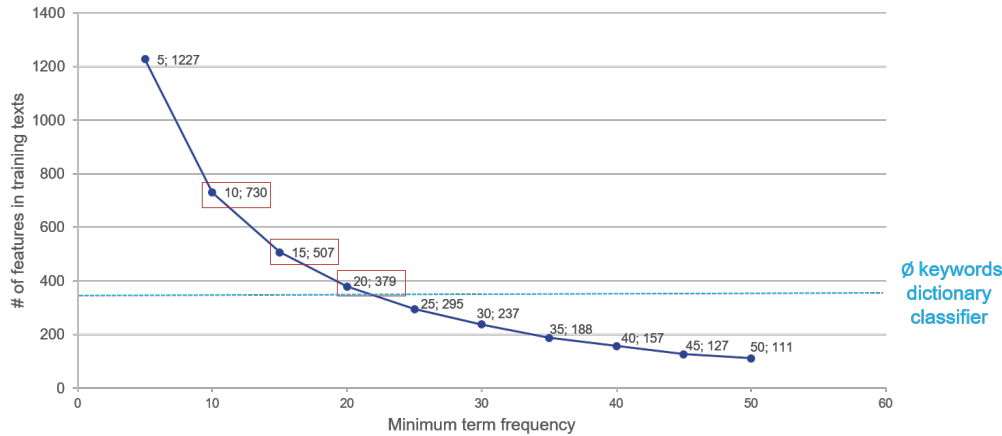


Figure 4.8: Pruning the training texts versus number of features.

4.4.2.3 Application of classification models

The data sample was split into a test dataset ($N = 5$; the first five reports from the sample) and the remaining dataset ($N = 47$). The *quanteda.textmodels* package (version 0.9.1) was used to build the classification model (Benoit 2018). The multinomial naive Bayes (NB)¹² (Manning et al. 2008) and linear SVM¹³ (Fan et al. 2008, Vapnik 1995) classifiers were used to make predictions for the class probability.

Previous surveys have revealed the NB classifier to be a suitable and well-performing classifier for document classification (Ting et al. 2011). The linear kernel of the SVM is recommended for text classification (Kowalczyk 2017). Each class was trained on textual data from the training set, representing content relating to the hypotheses in the seven predefined classes k . Both algorithms learnt from the training texts, as examples of input x for output y (Goodfellow et al. 2016). The results showed the estimated probability distributions for each document in each class, with documents able to belong to multiple classes (multi-labeled setting).

4.4.2.4 Validation of classification models

Various metrics are available for evaluating the performance of machine learning models (Anandarajan et al. 2019, Goodfellow et al. 2016, Sokolova and Lapalme 2009). This model's multi-labeled setting and low predictions (meaning a class was not well predicted for a document) were essential to answer the research question. The model's outcomes should support decision-making and save costs and resources, and there were no correct or incorrect predictions. No pre-labeled validated dataset was available, and hence no measurements and metrics (e.g., Anandarajan et al. (2019)) for a multi-labeled classification (Sokolova and Lapalme 2009) were feasible for use in this case.

¹²prior = "termfreq", distribution = "Bernoulli".

¹³weight = "termfreq", using *LiblineaR* package built in *quanteda.textmodels* package.

This section compares the results from the test and remaining datasets, and pre-processing of the training data using a difference score (see Equation 4.2). The applied score describes the difference between the average estimated class probabilities from the test and from the remaining dataset, as a measurement of convergence. A low number indicates better model performance as the test and remaining datasets provided similar results. Table 4.5 presents the results of the validation phase.

$$\text{Difference score} = \frac{\sum_{i=1}^k |\text{probability test} - \text{probability remain}|}{k} \quad (4.2)$$

where:

i = class number

k = amount of all predefined classes

Table 4.5: Difference scores for estimated class probability with NB versus SVM classifiers (min. term frequency for pruning training texts in feature selection phase in brackets).

	NB(10)	SVM(10)	NB(15)	SVM(15)	NB(20)	SVM(20)
Difference score	0.101	0.063	0.083	0.057	0.107	0.059

Overall, the linear SVM classifier yielded the best model output with training texts pruned to a minimum term frequency of 15. These pruned training texts still incorporated at least 40% of the keywords from the basic dictionary (67% for H1, 43% for H2, 21% for H3, 43% for H4, 23% for H5, 43% for H6, and 48% for H7). The output is depicted in Figure 4.9.

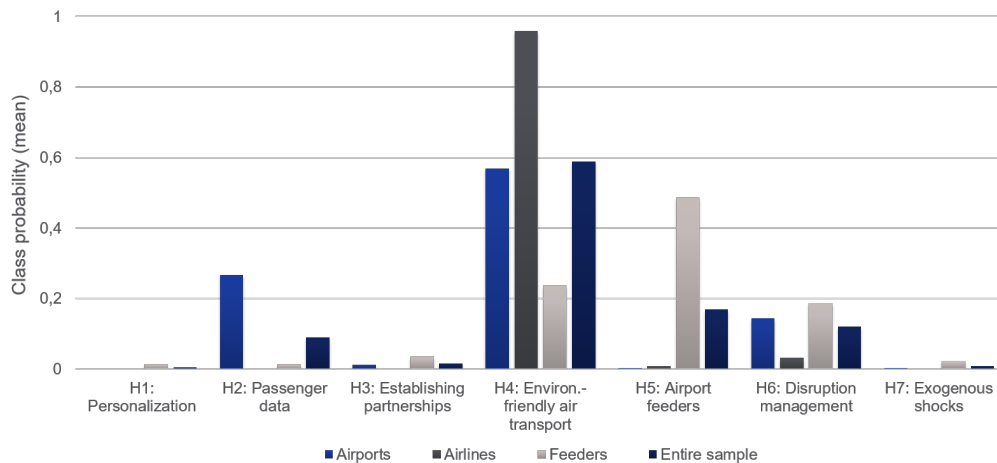


Figure 4.9: Final results from classification model output applying linear SVM to remaining dataset ($N = 47$) at TSP level.

4.4.3 Dictionary-based classifier versus supervised learning

Both the dictionary-based classifier and the supervised learning model answered the research question and enabled the development of dynamic models, updatable with new keywords, training texts and classes. However, the results differed between the classifier outputs (see Figure 4.6 and Figure 4.9). Several hypotheses (e.g., H1 and H6) had high frequency count matches using the dictionary-based method but showed a low predicted class probability in the supervised learning model. Pruning the training texts may have excluded rare keywords initially developed at the beginning of the study. As explored in Section 4.4.1, some keywords had a high frequency count match but were quite general, making it difficult to generate a high discrimination value for the hypotheses. This may also have been a sign of low relevance, as they only had a low frequency in the training texts for the supervised learning model. This is a key limitation of the dictionary-based classifier.

Table 4.6: Dictionary-based classifier versus supervised learning model to answer research question.

Criteria	Dictionary-based Classifier	Supervised Learning Model
Answers research question	Yes	Yes
Keywords required	Yes	No
Textual training data required	No	Yes
Retrieves new keywords	No	Yes
Rare keywords excluded	No	Possible (pruned texts)
Humans bias	Yes	Partly
Changes class meaning	No	Partly
Dynamic model (updatable)	Yes	Yes

Conversely, the advantage of the supervised learning method for the purpose of this study was the extraction of additional keywords to make predictions. This partly eliminated human bias from the keyword selection phase, although such bias might still have occurred in the selection of training texts. Including additional training texts might change the background and interpretation of the classes, as explored above. Table 4.6 presents a comparison of the two approaches. In summary, owing to its predominant advantages, the next section focuses on the supervised learning model using the SVM classifier.

4.5 RESULTS

This study aimed to answer the research question: *to what extent do TSPs consider prevailing factors in their strategic planning and incorporate them into their communications?* The results do not provide qualitative assessments, such as whether TSPs had positive or negative associations with the trends. Furthermore, the analysis was carried out on corporate documents containing high-level strategic management topics. Trends not communicated in these reports may already

have been implemented operationally. Internal corporate textual data would be required to investigate further.

4.5.1 Trend clusters

The outcomes from the supervised learning classifier model using linear SVM are shown in Figure 4.9. The results for all TSPs along the D2D air-travel chain show three main clusters (see Figure 4.10):

1. **Trends with higher relevance:** environmentally friendly air transport (H4)
2. **Trends with medium relevance:** disruption management (H6), passenger data (H2), and airport feeders (H5)
3. **Trends with lower relevance:** establishing partnerships (H3), personalization (H1), and exogenous shocks (H7).

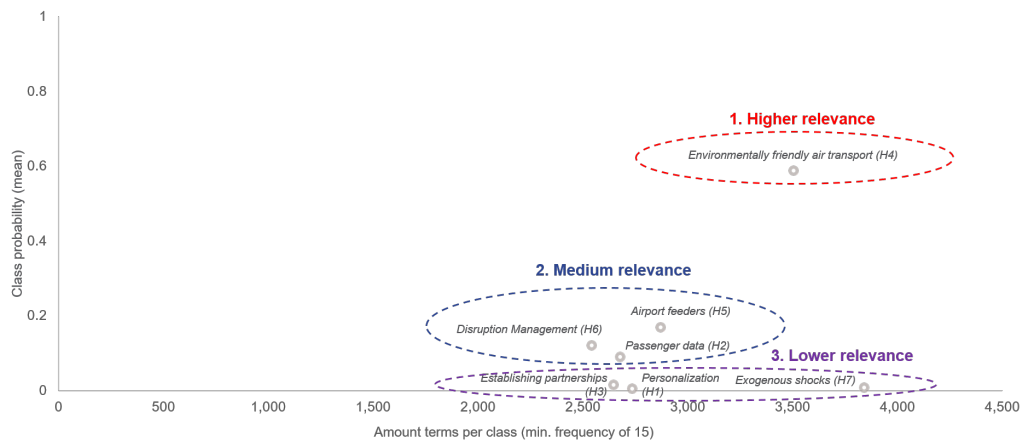


Figure 4.10: Classification model output in three clusters.

Figure 4.10 indicates no relationship between class probability and the number of terms per class in the training texts. The individual results for each TSP show large differences. The subsets of airport, airline and feeder data are explored in the next sections.

4.5.2 Airports

Fifteen reports remained in the airport subset after splitting the sample into test and remaining datasets. Measured by average values (means), H4 (Environmentally friendly air transport) has by far the highest probability, at 0.57. One reason may be that airports are very active in operating in an environmentally friendly way. As they are public service entities, they depend on public funding and tightly regulated. Thus, they have more need to publish on environmental issues. In the context of airports, and in light of the additional training texts, H4 may also encompass noise, animal protection, water management and recycling, as well as strategic partnerships with nature and animal conservation, which were not originally included in the hypothesis development and

also relate to the content of H3 (Establishing partnerships). New keywords and topics may have arisen in the training texts. As seen in this example, classes may develop beyond their original context when training texts are included in the supervised learning model. In addition, the high relevance of H4 may also be grounded in the selection of the analyzed data, as 27 sustainability-related reports formed part of the overall sample.

H2 (Passenger data) and H6 (Disruption management) are also predicted with comparably high class probabilities, of 0.27 and 0.14 respectively, in the textual data for airports. Airports seem to focus on offering environmentally friendly transport, leveraging passengers' data and managing disruptions. Class probabilities of almost zero are predicted for the remaining classes. Hence, these key trends seem to be less frequently covered in airports' textual data. The low class probability for H5 was expected (see Section 4.2).

4.5.3 *Airlines*

Two documents were used in the test sample, and the remaining 16 reports were included in the airline subsample. As shown in Figure 4.9, a very high class probability of 0.96 for H4 (Environmentally friendly air transport) is predicted by the SVM classifier model. This topic's high relevance was expected for airlines' textual data, but somewhat contradicts the industry's current damage to the environment through greenhouse gas emissions and other pollution. As this topic is of high strategic relevance and is driven by regulations and the public, it is unsurprising that airlines need to communicate about this challenge and explain themselves. Amongst various activities, airlines are investing in new fleets that reduce weight and fuel consumption. As previously discussed, this high prediction may also be grounded in a biased sample or the leveraging of additional training texts and the overall sample.

Low average class probabilities of 0.03 and 0.01 are predicted for H6 (Disruption management) and H5 (Airport feeders) respectively. The remaining hypotheses have a class probability of zero, and hence seem to be less frequently covered in airlines' reports.

4.5.4 *Feeders*

The highest relevance in feeders' data is indicated for H5 (Airport feeders), with an average class probability of 0.49. This class includes aspects like travel time, seamless and shared mobility, and on-demand solutions, as well as general mobility, such as urban, day-to-day transportation. It is hence unsurprising that feeder traffic providers show a high prediction for that class. Contrary to previous expectations, the second-highest class probability is predicted for H4, showing that environmentally friendly transport may also be relevant and important for ground services covering the D2K and K2G segments. An average class probability of 0.19 is predicted for H6 (Disruption management), which is assumed to be critical for all three TSPs. Low class probabilities are predicted for H3 (Establishing partnerships) and H2 (Passenger data). Novel transport modes and mobility solutions also rely on leveraging passengers' data and of-

fering innovative mobility solutions based on predictive models. The sample included public transport providers, but excluded mobility provider companies such as Uber, Blacklane and Free Now. The results might differ with an extended feeder sample, so further research is required. As in the overall sample, lower class probabilities are predicted for H₁ (Personalization) and H₇ (Exogenous shocks). Personalized and tailored mobility solutions for urban air mobility (on-demand and time efficient) lie far in the future, as currently only prototypes are available. Hence, personalization of airport feeders may also relate more to the future, with less relevance in current corporate reports.

4.5.5 *Managerial insights*

Before elaborating on practical managerial insights, it is necessary to consider the overall context within which the results must be interpreted. Annual reports were used as the object of analysis in this study. These types of report are subject to disclosure requirements, depending on the stock exchange on which the company is listed. Traditionally, disclosures have been very clearly oriented towards regulations and the financial market, explaining how past financial results were achieved. However, the content of reports has evolved in recent years. For example, the contents of sustainability reports, which were also part of this analysis, relate increasingly to governance and environmental issues. It is therefore unsurprising that keywords in the area of strategy occurred less frequently in the data sample, whereas keywords driven by regulation occurred more frequently. For instance, the results reveal a high class prediction for H₄, which is concerned with environmentally friendly air transport. In summary, we expected topics relevant to top management to be included in the reports. Other aspects might already be established in companies, in the context of the operational business rather than as top management topics.

This study is of benefit to the industry in several ways. First, the hypotheses developed in Section 4.2.2 provide a comprehensive overview of current trends and drivers of D2D air travel. Given the high practical relevance of this topic, these insights will support strategy- and decision-making in organizations seeking to become real D2D mobility suppliers. For instance, partnerships (H₃) are identified as a main driver of successful D2D products and services. In light of the current COVID-19 pandemic, potential partners might include suppliers of masks and hygiene products. Partnerships are also essential to mobility providers seeking to focus on seamless D2D air travel. Given that the main driver is personalization (H₁), these might be unconventional partners, as personalization is already strong in other domains (such as tech companies). Amazon, Google, Netflix, Apple, Facebook and Spotify already possess customers' data (H₂) and could improve passengers' personalized experiences throughout the travel chain, with regard to both actual travel and by-products. Of course, using personal data is only possible with passengers' consent. However, research shows a general willingness to do so if there is a benefit in return.

From the classification results, it can be concluded that not all TSPs are communicating much with regard to personalization (H₁) in the D2D air-travel

chain, and hence may not consider this trend to be strategically relevant. With more diverse passenger profiles and needs (Kluge et al. 2018b), this will become increasingly important. Other travel providers (platforms) outside the aviation industry are already starting to provide customized options for traveling through access to passengers' data (H2), potentially generating additional revenue. On the horizontal level, digital travel platforms like Google, Booking.com and Skyscanner may serve as D2D mobility integrators in all five segments. Platforms like EcoPassenger (2020) compare carbon dioxide emissions, energy resource consumption and other components of the entire travel chain to offer environment-conscious travelers the most environmentally friendly options.

Alongside the low relevance of personalization (H1), airports show a medium level of relevance of passengers' data (H2). As a Delphi-based scenario study recently revealed (Kluge et al. 2020), the future of D2D travel in the European market may be strongly influenced by these two key trends. To remain competitive, given the currently low demand for travel in many parts of the world, airlines are strongly advised to think about using passengers' data to personalize their travel. Improving airport feeders (H5) might also allow the creation of personalized D2D travel chains, especially in light of the COVID-19 crisis. Passenger segments such as business travelers and elderly passengers may increasingly demand contact- and touchless travel chains to minimize face-to-face contact and infection risks.

The results also depict a low relevance of TSPs' adaptation to exogenous shocks (H7). As recently observable in the market, aviation and mobility players need to learn to react much more flexibly to crises. TSPs must use this learned resilience in the next few years to meet passengers' day-to-day needs. For instance, flexible booking and ticketing systems might be better adapted to current demand. This will become increasingly important in strategic decision-making, as it is likely to take longer than expected for the travel industry to recover from the COVID-19 crisis (Škare et al. 2020). Improving airports' access and egress (H5) is shown to be highly relevant to feeder traffic providers. Airports are advised to increase their partnerships (H3) and improve airport feeder traffic (H5) by leveraging novel mobility concepts. These two key trends are interrelated, as increasing partnerships with novel mobility companies may lead to improved feeder traffic for passengers. Conversely, established feeder providers in this sample may be suitable partners.

Finally, the text classification model approach may allow companies to be assessed more cheaply and quickly. The classification model can be used to determine whether a company is communicating on the most pressing trends. It may also support companies' internal assessments of their own communications efforts, and help them to analyze stakeholders and competitors in the market. Other potential applications include mergers and acquisitions, the stock market, the investment sector, especially with respect to the often time-critical due diligence, and other consulting projects. In such deployments, one might start with a real-world business problem, investment level or stakeholder identification, and then determine data availability (Rochwerger 2019).

4.6 LIMITATIONS, FUTURE RESEARCH, AND CONCLUSION

4.6.1 *Limitations and future research*

The limitations of this study offer ample opportunities for further research to advance both the prototype models and data collection. The dictionary method has several limitations, such as simple representations derived by counting the frequency of pre-defined keywords (Watanabe and Zhou 2020), and the development of keywords outside the domain or with human bias (Grimmer and Brandon 2013). In this study, keywords in the dictionary were knowledge-based and developed by mobility experts, providing some external validity. Although this approach fitted the overall research goal, it can also be seen as a limitation, as humans may still miss relevant keywords or use the wrong terms. Watanabe and Zhou (2020) describe unsupervised topic models to detect keywords from textual data, such as Bayesian hierarchical topic modeling and LDA. These alternative approaches might counteract the limitations.

To exclude human bias in this study, a training set was constructed in the second step of the classification model development, using mainly domain-specific textual data. As described by Grimmer and Brandon (2013), human coding should best develop iteratively, meaning that several people are involved in the coding exercise, in order to avoid ambiguities or missing texts. In this regard, the model could be improved, as in this study only one coder was used. When looking at the training texts in detail after the pre-processing, we discovered some garbage words with no meaning, such as *one*, *also* and *can*. These could be excluded beforehand by using a customized list. However, there were very few garbage words compared with the number of valuable words, and their effect on this automated approach is considered to have been small. Furthermore, additional classifiers might be applied in the supervised learning model, or pre-processing of the training dataset might be adapted, such as using *2-gram* or *3-gram* (Kowsari et al. 2019). To overcome annotation and data biases, additional or different training texts might be used, such as excluding all academic data and fitting the model with corporate textual data only.

This study examined the extent to which hypotheses are considered by companies, as revealed in their communications in corporate reports. Hence, this study can provide answers if a trend is relevant, but cannot provide qualitative assessments, for instance of whether a company has positive or negative associations with a trend, or whether it occurs in the context of that hypothesis. In future research, sentiment analyses might deliver more detailed insights. Image recognition might be another complementary next step, as company reports also communicate through visual images, such as trees, animals, new projects or products and passenger groups, that are not captured in the classification model.

The overall sample also had limitations. Not all organizations, such as start-ups or private companies, publish annual reports. Hence, start-ups had to be excluded as possible feeder traffic providers to be analyzed in this study, but were included as keywords. As already touched on, data biases may also have been present in the data sample itself. We included many sustainability reports in the sample, so strong results for H₄ may be unsurprising. Using company

reports as data sources has limitations owing to content variance. There is no consensus on understandings of corporate sustainability in corporate social reports (Landrum and Ohsowski 2018), and some companies disclose more information than others, making it difficult to draw comparisons at a company level. There were also large variances in the raw data for different types of TSP. For instance, although the numbers of documents for all three subgroups were similar, the number of tokens within these documents varied greatly. After pre-processing the data, this imbalance disappeared, showing the critical importance of this research step. In terms of further data acquisition, both to increase the sample and to train the model, the data sources might also be improved by including more corporate textual data, such as website content, company presentations, investor relationship materials and quarterly reports. Some companies were excluded from the sample because their reports were unavailable in English. Translation would increase the sample size, although adding more reports to the sample might not improve the findings, while increasing time and costs (see Faraway and Augustin (2018)). To improve the approach and prototype and move towards further automation, ways to automate downloading of textual data might be developed. In this analysis, corporate textual data were downloaded manually. A suitable database or API might significantly improve this process and reduce the time taken to acquire data.

Finally, aviation and overall mobility are fast-paced industries influenced by large-scale global trends. The COVID-19 pandemic is currently impacting hugely on mobility companies, and the pressing issue of exogenous shocks is included as H7 in this analysis. Hence, the results might look different if the analysis were run using more recent corporate textual data, showing the limitations of the overall study design. Corporate textual data are dynamic, and trends may emerge or disappear over time, leading to a need to constantly adapt the hypotheses (classes) and classification model prototypes. This study can be considered as a starting point for such a dynamic trend-testing model. The developed dictionary (see Appendix Table B.5) can be re-used with additional or updated data, and expanded with further terms or hypotheses. This paper describes the development of the supervised classification model, allowing replication with new training data.

4.6.2 *Summary*

It is important to explore the entire D2D air-travel chain in order to improve the overall journey experience and tackle passengers' pain points. Trend analyses are essential for decision-making, and it is as yet unclear whether managerial insights from the literature are adopted as key management topics by TSPs. This paper contributes to research and the industry by providing an innovative approach for assessing the strategic relevance of D2D air-travel trends, using prototype multi-labeled text classification models.

The study explored whether airports, airlines and airport feeder providers TSPs along the travel chain consider and communicate findings from travel research. Fifty-two objects of analysis (annual corporate reports and sustainability reports) were gathered and analyzed using a dictionary-based classifier

model and a supervised learning model with the multinomial NB and linear SVM classifiers. Comparison of the models' outputs indicates that the SVM yields the best results for answering the research question. The results reveal that TSPs attach greater relevance to environmentally friendly air transport and related products. Disruption management, leveraging passengers' data, and improving airport feeder traffic through novel mobility concepts are trends considered to have medium relevance. Establishing partnerships, personalization of travel chains and constant adaptation to exogenous shocks, such as terrorism and pandemics, are given lower relevance.

Overall, the study provides a way to overcome the problem of collecting organizational data arising from public disclosure issues. It establishes trend hypotheses and a dictionary of keywords to test the strategic relevance of current D2D air-travel trends. The dictionary-based classifier and the supervised learning model are compared empirically. In summary, this novel approach offers many opportunities for further improvement and is transferable to other research questions and contexts for trend testing.

4.7 INTERIM CONCLUSION CLASSIFICATION MODELS AND OUTLOOK

The results of Chapter 4 shed light on the question of *to what extent do TSPs consider prevailing factors in their strategic planning and incorporate them into their communications?* Seven hypotheses (classes) and a related dictionary are developed describing D2D air travel trends. Two prototype multi-labeled text classification models assess the strategic relevance of prevailing key aspects in corporate textual data. Results reveal which trends have a higher, medium, or lower relevance regarding supply. The applied classification models conserve resources, are suggested to exclude human bias and systematically explore trends regarding supply.

For understanding trends in the context of D2D air travel in the European market holistically, the key user of the air transport system needs to be examined: the passenger in the demand role. That said, as described in Section 1.1.2, the COVID-19 pandemic has developed towards a global, ongoing endemic and created a *new normal*. During this research endeavor, the crisis seriously affects our everyday lives, the mobility sector, and the air transport system. Questions of how the air travel market within the transition times and the new zeitgeist looks like emerged. There is also the need to analyze this large-scale trend, provide a snapshot of the current situation, and support the industry with insights that allow to react and adapt towards the *new normal*. In line with the overall dissertation goal, this situation motivates an in-depth analysis of the passenger side.

Chapter 5 *sheds light on passengers' preferences within the transition towards the new normal*. For this purpose, a choice experiment with a sample of German passengers is conducted. As in Chapter 2, the long-haul flight is taken as an example. The study focuses on the air travel segment.

Air passengers' preferences in the transition towards the new normal¹

5.1 INTRODUCTION

5.1.1 *Motivation*

The ongoing COVID-19-induced crisis continues to affect the tourism and travel sector, and in particular air transport, heavily (Albers and Rundshagen 2020, Dube et al. 2021, Gössling et al. 2021, Maneenop and Kotcharin 2020). In 2020, offered seats for scheduled traffic were reduced worldwide by 50% (ICAO 2021). In the first three quarters of 2021, European travel demand (measured in RPK) was still 68% lower compared to pre-crisis levels in 2019, and German airlines served 74% fewer passengers (Bundesverband der Deutschen Luftverkehrswirtschaft 2021). The IATA (2021) forecasts that air travel within Europe will regain pre-COVID-19 levels by around 2024; however, former Chief Economist Pearce (24 November 2020) acknowledges many uncertainties in that regard.

European airlines are in a deep crisis. Governmental interventions, and in particular state aids for FSNCs, tie airlines' decision-making to governmental restrictions (Albers and Rundshagen 2020). Airlines are battling with a decline in sales and operating cash burn. For instance, Lufthansa reports significant revenue losses² with a net income loss of €6.7 billion for the financial year 2020 (Lufthansa Group 2021). Carriers need to find ways to win back passengers' trust and get them aboard as soon as possible. Next to ticket sales, ancillary (non-ticket) services are an essential revenue stream. Offering the right ancillary service mix can be one way to regain passenger market shares.

McKinsey & Company (2020a) reveal how COVID-19 changes consumers' behavior in all areas of our daily life: consumption, work, and also travel and mobility. Consumers are likely to have less discretionary income, be more price-sensitive, and focus increasingly on hygiene and health. Besides short-term hygienic measurements within air travel to mitigate the spread of the coronavirus, such as social distancing and obligatory masks (IATA 2020a), novel hygiene-related ancillary services might emerge for this transition time. Some passengers have not flown for a long time and, in addition to the pandemic, are influenced by the current sustainability debate. Dube et al. (2021) and Gössling et al. (2021) consider the COVID-19 related crisis as a chance for a fresh start into a passenger-centric and more environmentally friendly air transport system. With increasing knowledge of the coronavirus and its variants, safety and hygienic measurements, advancements in testing and treatment options, and rising vaccination rates in many parts of the world, it is necessary to look ahead into the *new normal*.

¹This chapter is based on Schmalz et al. (2021c): Schmalz, U., Ringbeck, J., Schlereth, C., Spinler, S., 2021c. Air passengers' preferences in the transition towards the new normal. *unpublished working paper*.

²For all business segments but air cargo.

Overall, the main difference between the COVID-19 pandemic and former virus outbreaks is twofold. First, combined with the high uncertainty, effects on air transport demand and supply are assumed to require several years for a full recovery, creating an endemic zeitgeist and a need for airlines to fight for passenger shares. Second, the COVID-19 crisis affects passengers' preferences. Given these developments, it is safe to say that the European air travel market is disrupted and currently in the transition towards a *new normal* leading to the question of how passengers' preference might have changed.

5.1.2 Research question

Although essential for the aviation industry, the scope of air travel preferences in this transition phase is not yet covered by research. The present study contributes to this gap by examining what the preferences of air travel passengers currently look like. The research goal is to *shed light on passengers' preferences within the transition towards the new normal*. We utilize a choice-based conjoint analysis with 269 German air travelers, measuring their preferences and willingness to pay (WTP) for attributes on a one-way, long-haul air trip. These attributes are presented as ancillary services, which are an essential revenue source for airlines. The WTP implicitly exposes and quantifies passengers' choices, and hence their preferences (Orme 2019). Segmenting respondents, we also explore the impact of demographics and travel behavior on these preferences. Results are discussed in the light of practical recommendations for airlines. The following three research sub-goals can be defined (adapted from König and Grippenkoven (2020)):

- **Identification of preferences:** To identify which ancillary services on a long-haul air trip affect passengers' utility in the *new normal*.
- **Sub-groups:** To examine the effects of trip purpose (business vs. leisure trips), frequent flyer membership, and demographics on the choice behavior of passengers.
- **Quantification:** To assess prospective passengers' willingness to pay for different ancillary services.

This study focuses on long-haul flights³ as this is a flight distance with low potential to be substituted by other means of transport, such as high-speed trains. Europe has moved from being a long-haul hub with 61 high-frequency⁴ long-haul routes towards only offering 19 high-frequency routes, a decline of 69% (Eurocontrol 2021a). Business-related long-haul air trips might take some time for full recovery, but leisure travel could recover sooner (Suau-Sanchez et al. 2020). Due to this catching-up effect, a unique moment is evolving for huge potential of yields on long-haul flights, making this distance an essential revenue stream for airlines, especially for FSNCs as they cover most long-haul

³There are no international standards for route definitions (Conrady et al. 2013). In this study, long-haul flights are defined as having a distance > 4,000 km, in line with Kluge et al. (2020), and Eurocontrol (2005, 2021a).

⁴> 4,000 km; routes offered at least 3 times a day return; total of 6 flights.

routes (Conrady et al. 2019). Further, the price elasticity of demand for long-haul flights is lower (Conrady et al. 2019), allowing more room for airlines to adapt pricing strategies, especially in a monopoly market situation, which might be created on some routes due to the reduced supply. The long-haul market also offers room for business model innovations: Bauer et al. (2020) elaborate on the benefits of deploying point-to-point ultra-long-haul services in the *new normal*, to connect safe regions without stopovers in infected areas. As long-haul routes are predicted to recover later overall (IATA 2021), there is still time to implement changes.

The paper is structured as follows. Section 5.2 provides an overview of existing literature. Section 5.3 describes the methodology, survey design, data collection, and sample of this study. Section 5.4 presents the econometric model, and Section 5.5 presents the results. Section 5.6 discusses the results, including a comparison with former studies and derivation of managerial insights. Section 5.7 concludes this paper.

5.2 LITERATURE REVIEW ON PASSENGERS' PREFERENCES

This section elaborates on COVID-19-related air travel trends for private and leisure passengers. Further, an in-depth review of airlines' ancillary services is provided, and previous works that examine passengers' WTP using a conjoint analysis are discussed.

5.2.1 COVID-19 and business air passengers

Mostly applicable to FSNCs (IdeaWorks 2020), business passengers yielded up to 50% of airlines' revenue pre-COVID-19 (Taneja 2017). As they are less price-sensitive (Conrady et al. 2019), business air travelers are a profitable customer segment for airlines. They value reliability, punctuality, flexibility, and comfort (Conrady et al. 2019). IdeaWorks (2020) forecasts a permanent drop in business trips of between 19% and 36%. The future is uncertain due to the *new work* phenomena of home office and online meeting solutions, and increased digital skills in the workforce mainly triggered by the COVID-19 crisis. There is debate around whether digital meeting solutions may partly replace air trips⁵. Recent COVID-19-related results by Suau-Sanchez et al. (2020) show that the recovery levels of business air travel depend on the travel context: trips for maintaining relationships might recover quickly, whereas meetings, incentives, conferencing, and exhibitions (MICE) air trips could take significantly longer to recover if pre-COVID-19 levels will ever be reached again. Ly (2021) argues that essential and important meetings will not be digitally replaceable. On the other hand, start-ups entering the market are relocating every work task into the virtual working world, including collaboration, chatting, events, and presenta-

⁵Pre-COVID-19 studies argue that meetings in person and business air travel will remain important, regardless of advanced meeting solutions (Schmalz et al. 2021a). Denstadli et al. (2013) show that many business travelers, however, do see a substitution potential to air travel, which might also be influenced by the available platforms and tools.

tions. Innovations, such as the hologram, can simulate face-to-face meetings and project participants' entire bodies (Portl 2021). Business passengers might also be driven by different levels of risk perception, which further influences travel demands (Liu-Lastres et al. 2021). Corporate travel budgets might be reduced due to cost pressure (Suau-Sanchez et al. 2020).

The future development of business travel remains uncertain, but reduced business air travel is very likely. As described by Puckett (2020), travel experts argue that airlines will start to compete to win business passengers back aboard, such as via enhanced bundled services and increased ancillary services, flexible loyalty programs, more functionality in airlines' apps, contactless travel services, and more private space. Given the significant revenue share coming from business air travel, it seems essential to shed light on business passengers' preferences in this transition phase to get them back on board.

5.2.2 *COVID-19 and leisure air passengers*

Business and leisure passengers vary in their requirements regarding air travel, and leisure air travelers are more price-sensitive (Conrady et al. 2013). Air travel for leisure purposes⁶ is also strongly impacted by the corona-related crisis (Gössling et al. 2021), but several voices argue that once the crisis is tackled, leisure air travel will recover quickly (IdeaWorks 2020); quicker, indeed, than business air travel (Suau-Sanchez et al. 2020). Ultimately, this is because it is human nature to travel and explore the world (Ly 2021). The confidence of leisure passengers will be the essential driver to regain their custom (IdeaWorks 2020), which is the main target segment and revenue source for LCCs on long-haul routes (Conrady et al. 2019, IdeaWorks 2020). Households' disposable income might be lower (McKinsey & Company 2020a), and affordable holiday destinations might gain momentum (Suau-Sanchez et al. 2020). As explored for business air passengers, tourists also demonstrate different risk perception levels, which influence their travel behavior (Neuburger and Egger 2020).

Leisure passengers return quicker to air travel, leading to airlines initially fighting for shares among them. Hence, it is essential to divide study results by travel purpose.

5.2.3 *Airlines' ancillary revenue*

In booking a flight, passengers purchase the core product of the physical transport from A to B, but they also buy supplementary services (Tsafarakis et al. 2018). The core product is characterized by safety, schedulability, and reliability (O'Connell 2011). Different cabin classes are available on long-haul flights: economy, economy premium (in four-class cabin concepts), business, and first (Conrady et al. 2019). On airline booking pages, customers can choose different cabin classes and services, and book a package containing the core product and additional services (Condor 2021b, Lufthansa 2021) depending on personal preferences and WTP.

⁶e.g., holidays or visiting friends and relatives (VFR).

Supplementary services, known as ancillary services or add-ons, generate additional (non-ticket) ancillary revenue (Conrady et al. 2019). They can be divided into four categories: 1) a la carte, 2) commission-based, 3) frequent flyer programs, and 4) advertising sold by the airlines (Conrady et al. 2013, Warnock-Smith et al. 2017). The a la carte category can be further subdivided into unbundled items and punitive charges (Warnock-Smith et al. 2017). Supplementary services can apply pre-, in-, or post-flight (O'Connell 2011), covering the entire D2D air travel chain. With further advances in data processing, digitalization, and personalization (Kluge et al. 2020), a fifth category of personalized ancillary service emerges (Shaw et al. 2021), which can also be offered re-bundled as branded fares for dedicated passenger segments (Conrady et al. 2019) (see Figure 5.1 for an overview).

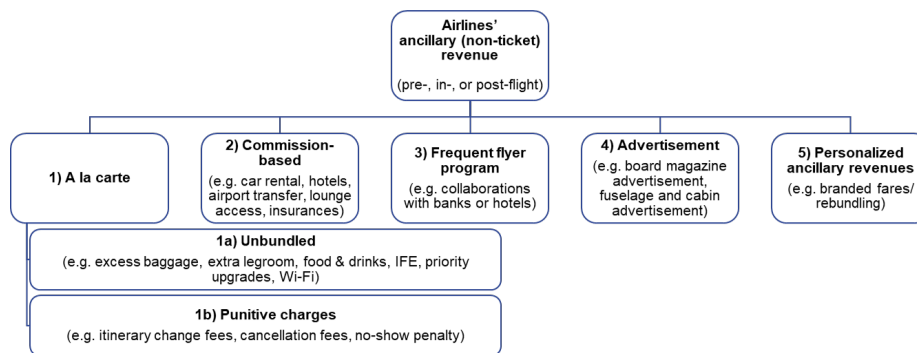


Figure 5.1: Airlines' ancillary revenue streams, based on the literature review (Batra 2017, Conrady et al. 2013, 2019, O'Connell 2011, Warnock-Smith et al. 2017).

The importance of ancillary revenue has grown in line with the emergence of LCCs but is now increasingly established in other airline business models too (Conrady et al. 2019). Already, pre-COVID-19, ancillary revenue was able to generate a large share of airlines' total revenue⁷ (IdeaWorks 2020, Shaw et al. 2021). Conversely, not all ancillary services defined in the literature improve the travel experience, such as credit card fees, no-show penalty or advertisements in the cabin. As elaborated by Shaw et al. (2021), we assume that passengers are increasingly becoming their own travel agents (dynamic packaging), and with supplementary services provided in the pre-, in-, or post-flight phase, it seems essential to understand their preferences. Most WTP and conjoint studies, therefore, focus on a la carte and commission-based ancillary services, as these enhance the journey and might be chosen by passengers.

5.2.4 Conjoint studies airline sector

The WTP shows consumers' valuation of a product or service, measured in monetary terms (Orme 2019). Different methods are available to measure either the revealed or the stated preference (Braidert et al. 2006, Raghavarao et al. 2011). Prior work applied direct customer surveys (Warnock-Smith et al.

⁷On average in 2019, 12.1% of airlines' total revenue, but can be up to 47% depending on the carrier (IdeaWorks 2020).

2017), which were also combined with ratings (Rouncivell et al. 2018). Previous airline-focused studies use the conjoint analysis (CA) successfully in assessing the pre-COVID-19 stated preference and WTP of air travel passengers (see Table 5.1 for an overview of published work).

Using a choice-based conjoint analysis (CBC), Chiambaretto (2021) explores passengers' WTP for five ancillary services for long-haul routes. He shows that leisure passengers have a higher WTP for ancillary services (excluding Wi-Fi).

Using again a CBC, Chiambaretto et al. (2013) measure the WTP for intermodal air-rail tickets for long-haul flights, surveying air travelers that had just arrived at a French airport. Intermodal services of this study include, for instance, early luggage check-in at train stations, or guaranteed rebooking in case of delays. Results reveal that leisure and business passengers consider price the most important criterion, followed by luggage handling and connecting time.

Hinnen et al. (2015) use an adaptive choice-based conjoint analysis (ACBC) to explore the WTP for supplementary green air travel products next to the ticket price, such as carbon offsetting schemes or organic in-flight catering. They survey Swiss air travelers, and results reveal that around 20% of Swiss passengers prefer to purchase green supplementary products.

Further studies explore carbon offsetting in greater depth. Ritchie et al. (2021) use a discrete choice experiment (DCE) among Australians to study the importance of product attributes that might lead to voluntary offsetting. Their results reveal that locally funded programs and the program's effectiveness are the preferred attributes of a voluntary carbon-offsetting program on the demand side. They develop three passenger sub-groups and show that younger travelers are more likely to pay for such programs. Business travelers and frequent flyer (FF) program members are less likely to pay for such initiatives.

Wittmer and Rowley (2014) survey economy class passengers (international sample) at Zurich Airport to rank eleven supplementary air travel services according to their importance. They distinguish between short- and long-haul flights and apply a CBC analysis. They detect that hospitality (seat selection, lounge access) and convenience (baggage delivery and priority parking at the airport) are the most valued services.

Ayantoyinbo and Boye (2015) apply a conjoint analysis to study passengers' domestic airline choices in Nigeria. Results reveal that, next to the price, flight convenience and frequency are the preferred attributes for passengers.

A conjoint analysis is also used for exploring the preferences of transfer passengers regarding airports (Chung et al. 2017) and for exploring the influence of codesharing agreements on passengers' behavior (de Jong et al. 2018).

Table 5.1: Review of previous work.

Author(s) (Year)	Title	Method	N	Studied Scenario	Studied Market
Ayantoyinbo and Boye (2015)	Preferences for Nigerian Domestic Passenger Airline Industry: Conjoint Analysis	CA	550	preferences for domestic airline choices	Nigeria
Chiambaretto (2021)	Air Passengers' willingness to pay for ancillary services on long-haul flights	CBC	454	long-haul flight; passenger types	Mainly France ⁸
Chiambaretto et al. (2013)	Measuring the willingness-to-pay for air-rail intermodal passengers	CBC	172	air-rail ticket for long-haul flight, all passenger type	France
Hinnen et al. (2015)	Willingness to Pay for Green Products in Air Travel: Ready for Take-Off?	ACBC	811	passengers taking a 4h flight in economy class	Switzerland
Ritchie et al. (2021)	Which types of product attributes lead to aviation voluntary carbon offsetting among air passengers?	DCE	998	domestic holiday air travel	Australia
Wittmer and Rowley (2014)	Customer value of purchasable supplementary services: The case of a European full network carrier's economy class	CBC	249	economy class passengers of FSNCs	Global sample ⁹

5.2.5 Contribution to the literature

Previous conjoint studies explore passengers' preferences and WTP values for different flight distances, cabin classes, and carrier types or reveal an enhanced understanding of carrier choices. It is shown that many conjoint analyses survey on a country or city level. To the knowledge of the authors, no recent conjoint study exploring preferences for ancillary services on long-haul flights within this transition time has thus far been published (cf. Table 5.1). The present study fills this research gap and explores air passengers' preferences and WTP values for ancillary services in the current transition phase into the *new normal*, brought about by the ongoing COVID-19 pandemic, high uncertainty, and changing market dynamics. It will further test how passengers assess newly emerging services. To gain these new insights, a CBC is utilized.

⁸Information requested from author: 89% of respondents are French; remaining respondents are from all over the world (with a majority of European respondents).

⁹Europe, North America, and Asia.

5.3 METHODOLOGY AND STUDY DESIGN

5.3.1 *Theoretical foundations*

The CBC is also known under the names DCE, discrete choice modeling (DCM), or discrete choice analysis (DCA) (Bredert et al. 2006, Orme 2017). The CBC (defined in this work as part of the DCE framework (Louviere et al. 2010))¹⁰ has its theoretical foundation within the behavioral theory of theory of random utility (RUT) introduced by Thurstone (1927). Based on further work by Luce and Tukey (1964) most notably among other developments, the RUT was derived into the logit model by McFadden (1974) using the Gumbel distribution for the error term to make choices easily translatable into probabilities (Train 2009). The conjoint analysis was developed further by Paul E. Green (Wharton School, University of Pennsylvania 2012). Since its initial development in the 1970s, the classical conjoint analysis developed as a method with its various forms (Green and Srinivasan 1978, 1990) and gained proliferation in many fields of research (Green et al. 2001) as well as for marketing purposes in the industry (Rao 2014, Simon and Fassnacht 2019).

5.3.2 *Applying the choice-based conjoint analysis*

To answer the research questions stated in Section 5.1.2, we apply the CBC. Several product profiles are presented simultaneously, and respondents are asked to choose their preferred one¹¹ (Bredert et al. 2006, Rao 2014). There is also the option to choose none of them, known as the “none alternative” or “no choice” option (Rao 2014). Each product profile contains various products attributes (e.g., price or color) at different levels (e.g., budget vs. premium). Each level provides a part-worth utility. As used in previous work (Anderhofstadt and Spinler 2020, de Jong et al. 2018, Fu et al. 2019, Wittmer and Rowley 2014), Sawtooth Software (2021a) Lighthouse Studio (version 9.11.0) is used for the questionnaire design, data collection, hosting, and parts of the analysis.

Unlike other WTP measurements, the CBC asks respondents indirectly (Bredert et al. 2006, Raghavarao et al. 2011) and requires them to make different trade-offs (Simon and Fassnacht 2019) while also providing the possibility to opt out. As elaborated in previous studies (Anderhofstadt and Spinler 2020) and by Rao (2014), this type of conjoint analysis depicts a more realistic buying situation on the real market. This approach works well for research into pricing management (Simon and Fassnacht 2019), and is also applicable to the purchase of airline tickets. With the proliferation of ancillary services, pre-COVID-19, passengers purchased additional services along with their plane ticket (especially for long-haul flights), such as seat selections (Zhou et al. 2020), check baggage or onboard Wi-Fi (Chiambaretto 2021). Hence, we consider the plane

¹⁰It should be noted that there is a debate around the differences between DCEs and classical CAs. Whereas Louviere et al. (2010) argue that traditional CAs are not based on the random utility theory, Orme (2017) contends that this is mainly a branding issue. In this paper, the DCE and DCA are assumed to be the same.

¹¹Compared to the early version of the CA, in which respondents rank or rate concepts (Green and Rao 1971).

ticket more as a package of different ancillary services (attributes), which can be well depicted in a CBC with choice sets. The attributes can be freely combined as additional possibilities for passengers in the booking process and pre-flight phase.

It also creates benefits for respondents: It is easy to answer, whereas other methodologies such as the ACBC might be too long and possibly create survey fatigue as described by Sawtooth Software (2018). As we aim to avoid dropouts and reduce experiment costs, we set the attribute number and required survey completion time low, which is another argument for choosing the CBC over other conjoint methods (Orme 2013).

5.3.3 *Study background*

We survey business and leisure passengers in Germany for their WTP for ancillary service packages on a long-haul flight. In this way, we can quantify passengers' preferences towards both new and existing services.

The study is based on a few assumptions. The COVID-19 pandemic triggers short-term shifts in consumers' behavior, seen in their increased focus on satisfying basic needs and a decline in demand for non-durable goods (Loxton et al. 2020). Aviation experts consider that passengers' preferences are also affected more long term (IdeaWorks 2020, McKinsey & Company 2020a, Song and Choi 2020). This study assumes a change in passengers' long-term preferences (choices) within the transition phase. We also assume that respondents behave in a way that maximizes their utility and choose alternatives that provide them with the greatest utility.

Song and Choi (2020) argue that stated preference models might not be suitable due to the high uncertainty of the COVID-19 crisis developments. Although we agreed with Song and Choi last year (2020), with increasing knowledge of the coronavirus, admissions and performances of vaccines, and advanced treatment options, it is also necessary to look ahead into the *new normal*, containing infection waves, periods with low infections, and the emerging endemic zeitgeist.

At the start of data collection on July 29th 2021, 52% of the German population were fully vaccinated (Federal Ministry of Health 2021). Infection rates were low in Germany, and passengers were transitioning into this *new normal*. Although travel from Europe to the United States (and other regions) was restricted in the summer of 2021, the German population was ready to travel again. This survey captures this spirit in a snapshot, driven both by the *new normal* and by the environmental debate that gained renewed importance during the COVID-19 crisis.

5.3.4 *Definition of attributes, levels, and travel scenario*

Based on these assumptions, respondents are presented in this survey with the following hypothetical scenario to take on a long-haul flight: *The Corona pandemic is over, all borders are open, and long-distance travel is possible again without restrictions. A large part of the world's population has been immunized. You have*

booked a long-haul flight in the premium-economy class from Frankfurt am Main to New York (one way). This route is 6,500 km long, and the day flight takes about 8.5 hours. You paid €550¹² for the flight ticket, including two free pieces of luggage of max. 23kg. In addition to the ticket, there are various services that you can book to make your journey as pleasant as possible. If these were the options, which of them would you choose?¹³

There is no standard on how to identify attributes and assign respective levels; however, these research steps often involve qualitative research such as expert interviews and focus groups (Louviere et al. 2010). Sawtooth Software (2021c) further recommends that attributes shall be independent and vary in degree of levels. To avoid bias, the number of levels shall be limited to between three and five. Levels shall be mutually exclusive, be concrete (unambiguous), and cover all main options of the product (Train 2009). To define attributes and levels for this study, we follow the three research steps shown in Figure 5.2.

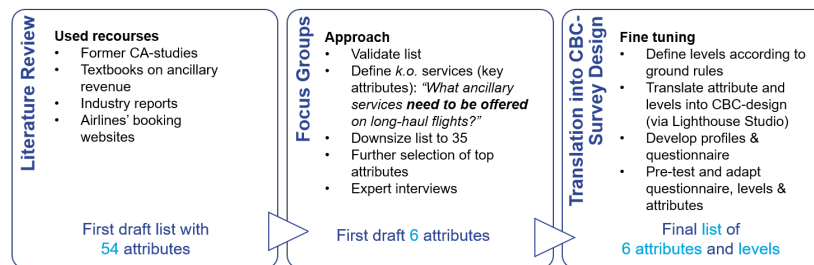


Figure 5.2: Three-step approach for the definition and selection of attributes and levels.

A systematic review and understanding of service attributes contributing to the utility of air passengers on long-haul routes within this transition time is lacking. Hence, within the first step, airlines' COVID-19-related service attributes are collected¹⁴ and structured along the framework of organizations towards crisis developed by Amankwah-Amoah (2020). The organizational framework distinguishes between short-term and long-term responses towards environmental shocks, taking COVID-19 as an example. Short-term responses within the airline industry could include, for instance, mandatory masks on board, disinfection of all surfaces, or temperature checks. These measures can be driven by firms or external forces, such as the government. Long-term respondents shall prepare airlines for their operations in the *new normal* world, demanding long-term and strategic thinking.

¹²Fare and flight length taken from RDC (2021) database, see Appendix Table C.1.

¹³Translated from German: *Die Corona-Pandemie ist überstanden, alle Grenzen sind offen und Fernreisen sind wieder ohne Einschränkungen möglich. Ein Großteil der Weltbevölkerung ist immunisiert. Sie haben einen Langstreckenflug in der Premium Economy Class von Frankfurt am Main nach New York gebucht (one way). Diese Strecke ist 6.500km lang und der Tagflug dauert circa 8,5 Stunden. Für das Flugticket haben Sie 550€ gezahlt, inkl. 2 Freigepäckstücke von max. 23kg. Neben dem Flugticket gibt es verschiedene Dienstleistungen, die Sie dazu buchen können, um Ihre Reise so angenehm wie möglich zu gestalten. Wenn dies die Optionen wären, welche davon würden Sie wählen?*

¹⁴Using industry reports and sources (AeroDynamic Advisory 2020, IATA 2020a, Lufthansa 2021, McKinsey & Company 2020a,b, Oliver Wyman 2020, Phocuswright Inc. 2020, Porsche Consulting 2020).

This list was supplemented with ancillary services collected in the literature review in Section 5.2.3 and with attributes used in previous work explored in Section 5.2.4, resulting in a first list of 54 attributes. As a second step, a focus group of seven people¹⁵ was carried out to downsize the list. Participants were asked to validate this list from a passenger perspective and indispensable criteria using the leading question *what ancillary services need to be offered on long-haul flights?* Afterwards, participants ranked their personal top six services.

Table 5.2: Interviewed experts (anonymized) for selecting attributes and levels.

#	Date	Interview partner	Interview content
1	March 2021	Airline consulting expert	Insight airline operating model
2	April 2021	Airline employee operations	Insight airline operations
3	May 2021	Airline employee marketing	Insight from marketing & passenger perspective
4	June 2021	Airline employee operations	Insight airline operations

Based on four interviews with airline experts and employees (see Table 5.2), the list was further downsized to six attributes, leading to the final list depicted in Table 5.3. Without any prohibitions, 384¹⁶ alternatives would be possible.

Table 5.3: Final attributes and levels used for product profiles.

#	Attributes	No. of Levels	Level 1	Level 2	Level 3	Level 4
1	Total price ancillary service upgrades	4	€100	€200	€300	€400
2	CO ₂ -compensation	2	not included	included		
3	In-flight meal upgrade	2	no upgrade	gourmet meal		
4	On-board hygiene upgrade	3	no upgrade	amenity kit	sanitized seat	
5	Seat upgrade (comfort)	4	no upgrade	empty seat next to you	emergency exit seat	business class seat
6	Multimodal ticketing: surface transport	2	not included	included		
<i>none alternative</i>						

1. Total price ancillary service upgrade: The total price (in €) for all upgrades within one option, on top of the ticket price. In the study scenario, it is also possible to choose none of the upgrades, which is the *none alternative* (no frills).
2. CO₂-compensation: This attribute refers to the compensation of the personal CO₂-emissions of the flight through the financial support of climate protection projects. Although the impact is relatively small, a successful carbon offsetting program can provide some relief (van der Sman et al. 2020), given the high overall CO₂-contribution of long-haul air travel of almost 52% of CO₂-emissions generated by European aviation (Eurocontrol 2021b).

¹⁵Representing German men and women at different ages between late 20s and mid 40s.

¹⁶Combining all levels: $4^2 \times 3 \times 2^3 = 384$.

3. In-flight meal upgrade: This attribute refers to a gourmet meal beyond the expected standard (e.g., sushi or a wide selection of wines). The WTP for an in-flight meal has also been tested in previous studies (Chiambaretto 2021, Chiambaretto et al. 2013, Hinnen et al. 2015).
4. On-board hygiene upgrade: Cabin hygiene influences passengers' comfort (Vink et al. 2012), and standards on board are already high. In addition to current procedures in place (e.g., FFP2 masks for passengers and crew are assumed to stay in the long term), the question emerges if passengers would be willing to purchase additional hygiene services. This is tested with two exemplary upgrades here: passengers can buy a personal amenity bag with hand sanitizer, gloves, and other utensils, or book the disinfection of the seat before the flight (incl. seatbelt and armrests). Passengers assess the hygiene amenity kit as the third important equipment for personal protection when traveling (Oliver Wyman 2020). AeroDynamic Advisory (2020) sees additional cabin disinfection as a driver to keep passengers' confidence high.
5. Seat upgrade: The comfort level aboard can be increased with more space and with a seat upgrade providing a higher seat pitch (Vink et al. 2012, Vink and Hiemstra-van Mastrigt 2011). Possible seat levels are a seat at the emergency exit for extra legroom (Condor 2021a) or a business class seat with sleeper beds (Lufthansa 2021).
6. Multimodal ticketing including surface transport: This attribute refers to a ticket that includes the journey to and from the airport by public transport, such as Rail&Fly, offered by Lufthansa (2019).

5.3.5 *Experimental discrete choice design and questionnaire*

In the last step, attributes and levels are translated into the CBC design. Non-scientific language is used, ensuring that all respondents have the same understanding of the travel scenario. The experiment is included in a questionnaire, which starts with an introduction, acceptance of the data protection policy, questions related to demographics and the personal air travel history, the travel scenario as described above, an introduction to the six attributes, as well as twelve product profiles (choice sets) with four alternatives and the *none alternative*. The design is fixed, showing the full product, and the tasks are randomized using the method of complete enumeration, which is similar to orthogonal and has minimum overlaps (Chrzan and Orme 2000). To support the respondents' use of multiple devices, a concept sorting for the ancillary service upgrade price is used following the natural level order starting with €100. To create a realistic buying situation, one prohibition rule is included: It is impossible to choose an option that does not contain any upgrade, as nobody is paying for nothing. Additionally, no price is shown more than once per task. An example choice set is depicted in Figure 5.3. Before the questionnaire terminated, the question of whether respondents answered from the perspective of an individual or a business traveler was included as a screening question.

	Option 1	Option 2	Option 3	Option 4
Total price flight upgrades:	€ 100	€ 200	€ 300	€ 400
CO ₂ -compensation:	✓	✓	✗	✗
In-flight meal upgrade:	✗	✗	gourmet meal	gourmet meal
On-board hygiene upgrade	sanitized seat	✗	amenity kit	sanitized seat
Seat upgrade for more comfort:	✗	business class seat	emergency exit seat	empty seat next to you
Multimodal ticketing to and from airport:	✓	✗	✗	✓
	Select	Select	Select	Select
Option 5				
I wouldn't choose any of these.				
	Select			

Figure 5.3: Example choice set in Lighthouse Studio (translated from German).

Data protection according to European regulations is fully respected in this research project (European Commission 7.6.2021, European Parliament 27.4.2016). All answers are voluntary and processed anonymously. No personal data, IP addresses, information on the browser used or the operating system are collected by the research team. It is not possible to trace the answers back to individuals. The survey is hosted on Sawtooth servers in the US. An additional data processing agreement is signed and executed to ensure the study is compliant with the General Data Protection Regulations (GDPR) (European Parliament 27.4.2016). All participants are sufficiently informed via the data protection policy at the beginning of the questionnaire, to which everyone also actively agreed.

Generating a report with 300 dummy respondents, the level balance is tested. The test report shows that all levels within one attribute are shown equally¹⁷. The strength of design (Sawtooth's D-efficiency) for the model is 1654.45278, and the standard errors for all attributes levels met the threshold of 0.05 or smaller, as defined by Sawtooth Software (2021b).

The questionnaire is pre-tested with 30 respondents in two pilot rounds. The pre-test groups are asked to use computers, mobile phones, and tablets to ensure that the survey is suitable for all devices. The questionnaire and the CBC-design was adapted based on feedback from both pre-test rounds.

¹⁷Frequency of 3,600 per level for 4-level attributes, frequency of 4,800 for 3-level attributes, and frequency of 7,200 for 2-level attributes.

5.3.6 *Data collection, consistency check, and representativity*

The data was collected in eight weeks, from the end of July until mid-September 2021. The questionnaire was distributed via an online link. Respondents were recruited via multiple channels. The survey was posted on social media platforms, such as Facebook, LinkedIn, Xing (German business-oriented online social network), Twitter, and Research Gate. Social media platforms have already been successfully used in previous CBC-studies for recruiting purposes (König et al. 2018). Overall, 396 items of usable respondent data were collected, including both completes and incompletes. Before starting the analysis, a consistency check was conducted. Only completes, respondents who currently live in Germany, and those who passed the screening question¹⁸ were included leading to a final sample of $N = 269$. As depicted in Table C.2, the model performance does not decrease with a lower number of respondents (269 vs. 396).

Orme (2019) confirms that a sufficient sample size for conducting a conjoint analysis between 150 and 1,200 respondents but stresses that a minimum of 300 respondents would be required for a robust quantitative study. Sawtooth Software (2018) recommends a minimum of over 200 respondents for conducting a choice-based conjoint analysis.

As this study aims to provide a snapshot within transition times, the sample size of $N = 269$ is considered sufficient. Due to the additional consistency checks described above, we are also confident of analyzing a high-quality data set.

5.3.7 *Sample composition*

On average, respondents took 9.17 minutes to complete the questionnaire¹⁹. The demographic characteristics and air travel behavior of the sample are summarized in Table 5.4. The sample splits almost equally between men (52%) and women (47%), excluding 1% of respondents whose gender is unknown. As also seen in Fu et al. (2019), the younger respondents aged between 26 and 35 years are over-represented and constitute 45% of the sample. Among all age groups, 61% of respondents work full- or part-time. Only 4% of respondents are retired, and 18% are still in school. The sample is highly educated given that 87% earned a university or college degree, including PhDs. Most respondents live in a two-person household (41%).

All respondents have flown before. Over two thirds have flown within the last three years. A total of 46% of respondents had no air travel plans for 2021 at the time of the data collection, which could be due to the high uncertainty based on the COVID-19 pandemic. If an air trip is planned, this is in 118 cases a medium-haul flight, followed by 41 long-haul flights. The sample splits almost equally between members (49%) and non-members (51%) of a FF

¹⁸Respondents whose answers regarding their primary travel purpose and survey perspective did not match were excluded. This procedure filtered out speeders, inattentive respondents, and other noise that might decrease the data quality.

¹⁹Outliers who needed more than 60 minutes are excluded from this calculation as it is assumed they stopped the survey in between.

program. Among the respondents, 12% fly mainly for business purposes, with most business travelers being male.

Table 5.4: Demographic characteristics and travel behavior of sample.

Variable (Demographics)	Sample Characteristics (N = 269)
Gender	
<i>male, female, other, n/a* (*prefer not to answer)</i>	52%, 47%, 0%, 1%
Age group (years)	
<i>18 - 25, 26 - 35, 36 - 45, 46 - 55, 56 - 65, >65, n/a*</i>	13%, 45%, 23%, 7%, 7%, 4%, 0%
Household size (number of persons)	
<i>1, 2, 3, 4, 5, >5, other, n/a*</i>	25%, 41%, 16%, 12%, 4%, 1%, 0%, 1%
Household income levels (€, after tax)	
<i>up to 1,000, up to 2,500, up to 5,000, up to 7,500, >7,500, n/a*</i>	10%, 14%, 32%, 16%, 16%, 12%
Education	
<i>no school-leaving qualification, secondary school diploma, secondary modern school diploma, A-levels or equivalent, completed vocational training, university / technical college degree, PhD / doctoral degree, other, n/a*</i>	0%, 0%, 0%, 8%, 4%, 74%, 13%, 0%, 1%
Employment	
<i>in training (studies), employed part-time, employed full-time, self-employed, without employment and seeking work, without employment and not seeking work, retired, unable to work, other (please specify), n/a*</i>	18%, 13%, 51%, 11%, 1%, 1%, 4%, 0%, 1%, 0%
Variable (Travel behavior)	Sample Characteristics (N = 269)
Main travel purpose	
<i>private, business, n/a*</i>	88%, 12%, 0%
Frequent flyer	
<i>no, yes, n/a*</i>	51%, 49%, 0%
Last flight	
<i>2021, 2020, 2019, 2018, 2017, 2016 or earlier, I have never flown before, n/a*</i>	39%, 19%, 30%, 4%, 3%, 5%, 0%, 0%
Travel plans (counts; multiple answer possible)	
<i>no, yes (short-haul), yes (medium-haul), yes (long-haul), n/a*</i>	113, 37, 118, 41, 1

The sample represents air passengers in Germany well. Looking at the passenger survey results from Munich Airport (2020) with a gender split of 52% male and 48% female passengers, the gender split in the sample is the same. Although the general share of business travelers in Germany is about 36% (Munich Airport 2020), the split on long-haul flights from Germany to the United States (which is the route used in this scenario) is different: Taking business class seats as a proxy for business travelers, the split is around 84% private travelers and 16% business travelers (OAG 2018)²⁰, which is comparable to the sample's share of 12% business travelers. The passenger survey from Munich Airport (2020) depicts similar age groups. Even though the age is not directly comparable, the age structures from both surveys are similar: Young passengers represent the largest share (46% ≤ 39 years in the Munich passenger survey versus the collected sample with 58% ≤ 35). People in middle age (middle-agers) (aged 40-59 years) make up around 41% in the Munich Airport passenger survey and 31% (age 36-55 years) in the collected sample. Baby

²⁰Of the 6,378,011 planned seats, 1,011,796 are business class seats, looking only at one-way flights from Germany to the United States.

Boomers and retirees make up 13% (60+ years) in the Munich passenger survey and 11% (56+ years) in this data sample.

5.4 ECONOMETRIC MODEL AND ANALYSIS

5.4.1 Hierarchical Bayes estimator

For developing the econometric model to analyze the data, we build on the assumption of respondents' utility maximization and the RUT. The RUT is the foundation for this discrete choice experiment and assumes that the utility U for choices j of a respondent n is latent and contains two components: 1) a systemic and explainable V and 2) the random, non-explainable component epsilon ε . The equation of the RUT follows (Train 2009, p.34):

$$U_{nj} = V_{nj} + \varepsilon_{nj}(\forall j) \quad (5.1)$$

where:

n = respondent

j = choices (alternatives)

U = utility

V = explainable (systematic) component

ε = unobservable (random) component

The error term is an individual and stochastic factor that impacts human choices (Louviere et al. 2010, Thurstone 1927). As we cannot measure the error term, it is treated as a random variable. Based on McFadden (1974), the error term is always identical and distributed using the Gumbel (extreme value) distribution with the variance $\pi^2/6$.

The utility is not observed directly, but choices are. The observable component V is assumed to be linear: $V_{nj} = \beta'X_{nj}$. Let X_{nj} be a vector with all attribute levels describing the choice and β being the structural parameters. Given that in this study set-up a passenger n will choose the ancillary service upgrade option j among all alternatives that provide them the greatest utility, the individual-level utility function for could be stated as follows in Equation 5.2 (adapted from Chiambaretto (2021)):

$$V_{nj} = \sum_p \beta_{pjn} \text{upgradeprice}_p + \beta_{nj} \text{offset} + \beta_{nj} \text{meal} \\ + \sum_h \beta_{hjn} \text{hygiene}_h + \sum_s \beta_{sjn} \text{seat}_s + \beta_{jn} \text{multimodal} \quad (5.2)$$

where:

β = structural parameters

p = ancillary service upgrade price

h = hygiene upgrade

s = seat upgrade

Deriving the RUT into the logit equation without the error term, choices are easily translatable into probabilities (Train 2009). After some manipulation²¹, the logit model can be derived (Train 2009, p.37) as stated in Equation 5.3.

$$P_{ni} = \frac{e^{\beta'X_{ni}}}{\sum_j e^{\beta'X_{nj}}} \quad (5.3)$$

where:

P_{ni} = probability that n chooses i

The logit model translates utility and estimating part-worths into the probability of selecting a product or service. Equation 5.2 contains observable information presented by the six attributes and respective levels. Still, more ancillaries and other individual and non-observable factors presented by the error term exist. Their effects are not measured in this experiment. The authors are aware of this. Due to the attribute pre-selection process, most prevailing ancillaries are included. It is assumed that the utility is presented well, making the logit model a suitable approach.

The unknown beta parameters will be estimated using the hierarchical Bayes method. Using Sawtooth's Lighthouse Studio, a hierarchical Bayes multinomial logit (HB MNL) model with a Monte Carlo Markov Chain algorithm is built to analyze the choice data (Sawtooth Software 2021c). The HB MNL model has been applied in other CBC-studies (Schlereth et al. 2018, Schreiber and Baier 2015) and borrows information from higher aggregated population levels to enrich lower individual levels. The HB method estimates average utilities on an aggregated sample level and part-worth utilities on an individual level (Sawtooth Software 2021b), making it possible to segment the sample into sub-groups. A more detailed explanation of the HB MNL model is provided by Schlereth et al. (2018) and Train (2009).

5.4.2 Data analysis

In total, 269 respondents completed twelve choice sets each, leading to 3,228 collected choices. Frequency counts are generated to explore the data and conduct a sanity check. The counts in Table C.3 in the Appendix depict a proportion showing "[...] the number of times an attribute level was chosen relative to the number of times it was available for choice." (Orme 2019, p.79). All main effects (differences between levels) are significant ($p < .01$).

In the next step, the HB model is built. Different numbers of iterations are applied, and the model performances are compared to choose the optimal model setting for reaching convergence. For that purpose, the average measurements of the percent certainty (Pct. Cr.)²², root-likelihood (RLH), average variance, and root mean square (RMS) are used (see Table C.2 in Appendix).

²¹See Section C in the Appendix and Chapter 3 in Train (2009) for detailed algebra.

²²The Pct. Cr. ranges from 0 to 1 and can be treated like the R-squared value. According to a meta-study by Orme (2010), Pct. Cr. values for an experiment with four alternatives typically range between 0.6 and 0.8²³. All of the tested models yield this range.

The computing time remains mostly below five minutes, indicating that the computing time in this study is acceptable. A higher number of iterations did not lead to a notable increase in the model's goodness of fit, indicating convergence and that measurements oscillate around the final model values (Sawtooth Software 2021b). The fit statistics and the respective models' plots (see Figure C.1 in Appendix for an example of the final model) are inspected and compared. The HB mode with 40,000 burn-in iterations and 40,000 sample iterations is chosen as the optimum converged model with the highest average Pct. Crt. value of 0.752. All following sections refer to the results of this model. The HB model is used to estimate the attribute importance scores for the entire sample (reported in Section 5.5.2) and for sub-groups (reported in Section 5.5.3). Results are also the basis for calculating the WTP values, reported in Section 5.5.4.

Due to a large number of iterations in the posterior distribution and high likelihood of significance, significant level tests are generally not required (Schlereth et al. 2018). However, we reported the confidence intervals confidence intervals (CIs) at a 95% level, both according to the Frequentist notion and the Bayesian way as described by Orme and Chrzan (2017) using the 40,000 sorted alpha draws after convergence and reporting the 2.5th and 97.5th percentile (see Table C.4). Most CIs do not overlap, indicating significance for these utility differences. The Bayesian CIs for the levels amenity kit, sanitized seat, empty seat next to you, and emergency exit seat overlap slightly.

To examine alpha draws by sub-groups, covariates are developed. Bayesian level-by-level significance tests with the alpha draws are conducted to determine the degree of certainty for group differences as described in Orme and Chrzan (2017) (see Table C.5).

Using the Lighthouse Studio market simulation, scenarios are developed to estimate passengers' WTP values for ancillary services. Sub-group differences for ancillary service packages are explored. Regression analyses are conducted to further explore the significant drivers on passengers' market shares.

5.5 RESULTS

Applying the presented Hierarchical Bayes estimator, this section focuses on three main research results: 1) the identification of preferences, 2) the examination of sub-groups, and 3) the quantification of passengers' WTP.

5.5.1 Results of stated choices

The data of the count analysis (see Table C.3) show the expected behavior. The lower ancillary service upgrade packages were selected more often (the package priced €100 was selected in 34.60% of all choice sets) and less so the more expensive ancillary service upgrade packages (the package priced €400 was selected in only 2.60% of all choice sets). The *none alternative* was selected in 41.70% of cases, meaning that no offered ancillary service upgrade package was purchased. Looking at the ancillary services, the business class seat as a comfort upgrade was chosen the most, selected in 26% of all times it appeared. The

other seat upgrade options, an empty seat next to you and an emergency exit seat, were selected together 26.50% of all times they were shown. These counts already indicate a high preference for seat upgrades. The CO₂-compensation was selected in 20.90%, the multimodal ticket in 17.50%, the gourmet (meal) upgrade in 16.50%, the sanitized seat (hygiene upgrade) in 16%, and the amenity kit (hygiene upgrade) in 14.90% of all times they appeared.

5.5.2 Identification of preferences: average importance scores

The relative importance is analyzed to identify which ancillary services affect passengers' utility. Figure 5.4 depicts the average utility scores (in %) for the sample. These scores indicate the influence of the tested ancillary services on passengers' choices on a long-haul flight. The score must be interpreted relatively among the six tested attributes in this choice experiment (Orme 2019).

It can be seen that the total upgrade price is the most important attribute and has the greatest influence on passengers' choices, with an importance score of 44.38% [42.77%; 45.99%]²⁴, followed by the seat upgrade with an importance score of 22.64% [21.15%; 24.13%]. The CO₂-compensation reveals an importance score of 14.35% [13.07%; 15.63%], followed by the multimodal ticketing upgrade with a score of 7.90% [7.26%; 8.55%] and the in-flight meal upgrade with a score of 5.77% [5.24%; 6.29%]. The on-board hygiene upgrade, with 4.97% [4.57%; 5.36%] has the lowest influence on passengers' choices.

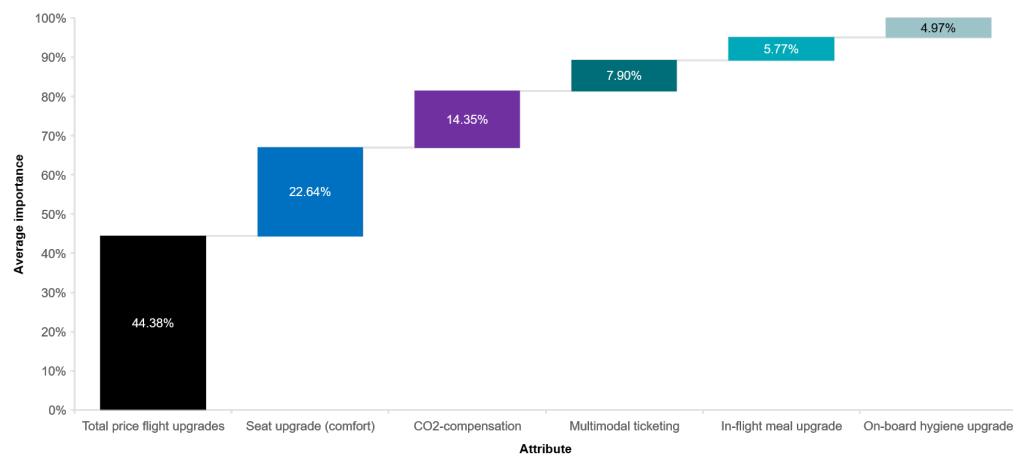


Figure 5.4: Relative impact of ancillary services on passengers' choices - overall sample.

Figure 5.5 depicts the relative part-worth utility level by level using the raw scaling method. Utilities within one attribute sum up to zero (except the no-purchase option), and negative values do not indicate that a level is per se unattractive (Orme 2019). The no-purchase option brings the highest average utility, as respondents chose it in 42% of cases. In line with the importance scores, it can be seen that business class seats bring the highest utility as a possible seat upgrade. CO₂-compensation and the multimodal ticket upgrade also provide a higher overall utility. The emergency exit seat upgrade has a utility of almost zero, and passengers do not seem to see any benefits, possibly as the

²⁴[lower 95% CI; upper 95% CI].

emergency exit seat does come with a responsibility in case of emergencies and some other limitations (personal items must be stored in overhead bins during take-off and landing, for instance). It is also depicted that the newly emerged ancillary services related to COVID-19 - the amenity kit and sanitized seat as hygiene upgrade - both seem to bring limited overall utility and hence do not seem to affect passengers' preferences significantly. Looking at the relatively low standard deviations of the on-board hygiene upgrades in Table C.4, one could also assume that there is consensus on this among the passengers.

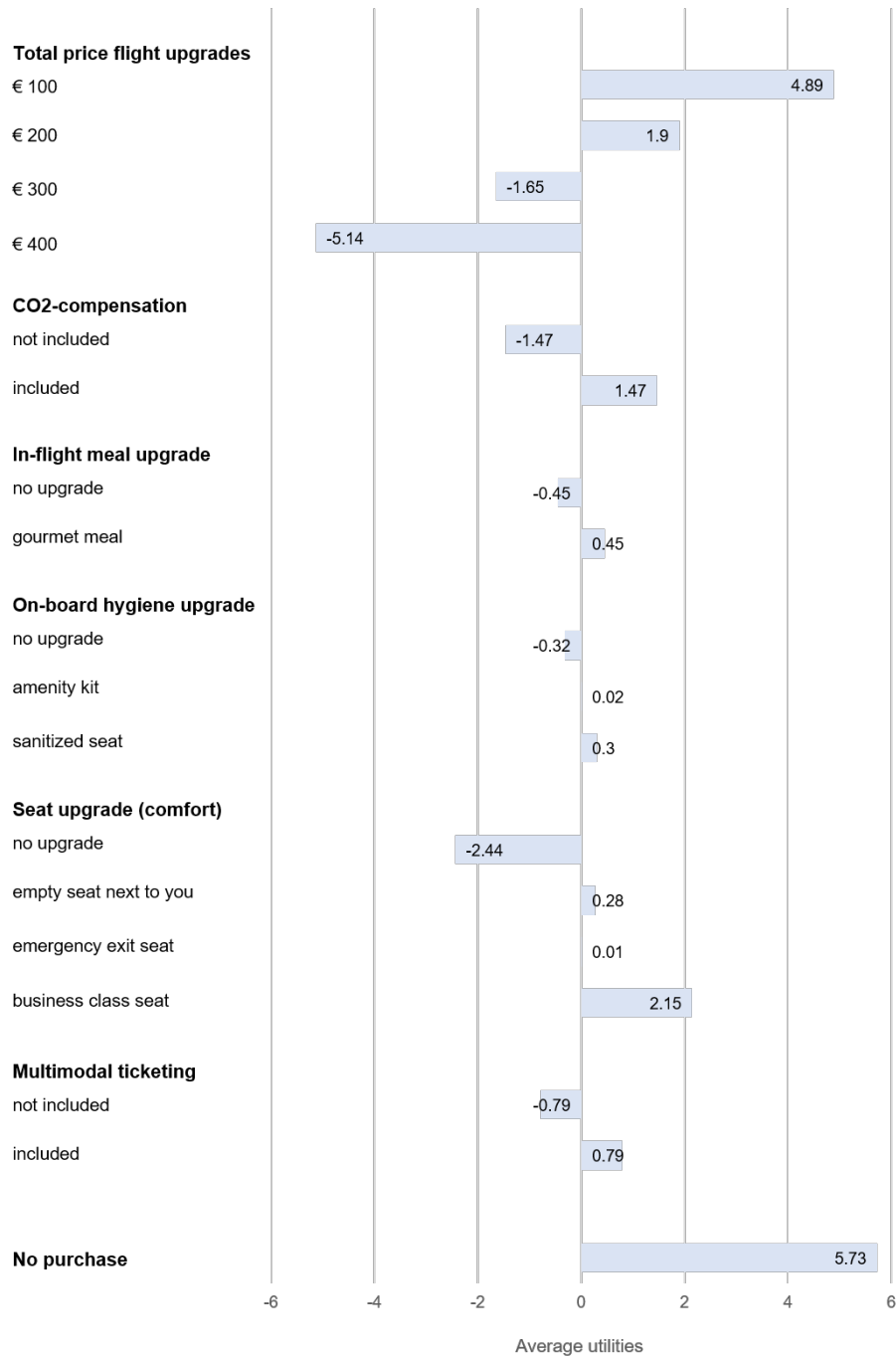


Figure 5.5: Average utilities of ancillary services for a flight upgrade.

Analyzing respondents' comments, passengers mostly agree that adequate on-board hygiene should be standard. The WTP for additional hygiene upgrades is low, with some passengers even considering it an impertinence to sell such services. Many comments support the strong preference for in-flight seat upgrades and more space aboard. The climate impact of aviation was also commented on strongly, albeit from different points of view: some passengers consider CO₂-compensations through an airline as rather critical and not effective. Others see compensation as indispensable, indicating that it should no longer be optional or offered as an add-on at the same level as gourmet meals or other ancillaries given our current climate crisis. The comments suggest that there is a clash of opinions here.

5.5.3 *Preferences by sub-groups*

Comparing male and female passengers in Table C.5, it can be seen that female passengers have a higher preference for choosing a CO₂-compensation as an add-on. Further, women have a higher preference for multimodal ticketing, which includes public transport as an airport feeder. Male passengers, on the other hand, show a higher preference for choosing the business class seat upgrade, whereas women have a higher preference for upgrading towards an empty neighbor seat. Women have a greater preference for a sanitized seat than men. Both men and women have a similar preference for the in-flight meal upgrade, with a higher tendency to upgrade to a gourmet meal among men. Overall, the preference differences among male and female passengers can be confirmed with an 82% degree of certainty.

Further, business and leisure passengers are compared. As expected, business passengers are less price-sensitive and show a higher preference for the business seat upgrade and the meal upgrade. Leisure passengers show a higher preference for CO₂-compensation and multimodal ticketing. Both subgroups show a low preference for hygiene upgrades. These preference differences according to the travel purpose can be confirmed with a 77% degree of certainty.

Comparing the sub-groups of members and non-members of a FF program, it is most notable that non-members have a higher preference for choosing CO₂-compensation and multimodal ticketing than members do. Further, non-members have a greater preference for an empty neighbor seat than members, whereas members have a higher preference for the business class seat upgrade and the gourmet meal. The preferences for the hygiene upgrade between those two groups are similar. Non-members are more price-sensitive when it comes to the ancillary service upgrade packages. Overall, the preference differences among members and non-members can be confirmed with a 78% degree of certainty.

5.5.4 *Quantification of passengers' willingness to pay*

Importance scores as presented can be biased, as they consider extreme outliers from the collected data (Orme 2019). Within this section, the results are supplemented with market scenarios, known as choice simulations (Orme and

Chrzan 2017). Results show the share of preference (share of choice) for an ancillary service. Results also reveal passengers' monetary WTP values, making the outcome useful for managers and non-researchers. Including this competition depicts a more realistic market scenario for reflecting passengers' behavior in the real world, as WTP values would look different in a monopoly, for instance (Orme 2021).

5.5.4.1 Market scenario

Before the analysis, some settings were made in the market simulator. The *share of preference* simulation method is utilized. This method apportions respondents' package choices according to the logit equation (see Equation 5.3), meaning a respondent can split their choice among several packages. In total, 1000 simulation sets are completed following the sampling of scenario (SOS) approach (Orme 2021). The SOS approach develops random upgrade packages specifications among all competitors and ancillary services. Using this approach, the simulator explores all possible reactions from competitor airlines. The WTP value is equal to the price delta associated with a product enhancement compared to a basic product that is needed to regain the original preference share by customers before the enhancement. In this study, it would be no upgrade versus an ancillary service. The simulator conducts several simulations until this price delta is found (Orme 2021).

Looking at the planned flight schedule from Frankfurt Airport (FRA) to New York Airport (JFK) (OAG 2018), four airlines cover this route: Condor, Lufthansa, Delta, and Singapore Airlines. The number of competitors is hence set to three, and the fourth airline is the reference airline. The reference airline in this case study is Lufthansa, which offers all ancillary services. The results are generalizable and valuable for all airlines that offer all ancillary services. The no-upgrade (not included) levels are the references, meaning that the monetary WTP values must be interpreted in relation to these reference levels. The seat upgrade level of an emergency seat is excluded in the simulation, as its part-worth utility score is almost zero (see Table 5.5), indicating that this ancillary does not create value for passengers. The ancillary service upgrade price is transformed into the price variable. Only Lufthansa (Lufthansa Innovation Hub 2021) and Singapore Airlines (Singapore Airlines 2021a) offer the CO₂-compensation option; hence, it is adapted in the simulation that only two competitors provide this ancillary service. The no-purchase option is included as passengers have already bought their tickets and do not have to buy an ancillary service (as also stated in the choice experiment)²⁵.

Within the scenario, perfect market conditions are assumed. Ancillary services are equally available and offered by all airlines, besides the constraints elaborated above. Passengers have perfect information and equal awareness of each service. All airlines have an effective marketing and sales force.

²⁵All WTP values decrease when running the same simulation without the *none alternative*.

Results of the market simulator are depicted in Figure 5.6, showing the median WTP values for each ancillary service in relation to the reference level²⁶. Results reveal that passengers are willing to pay €139.01 for CO₂-compensation, €57.67 for a multimodal ticket, and €35.60 for an in-flight meal upgrade. Passengers are willing to pay €180.10 for a business seat or €111.52 for an empty neighbor seat, compared to no seat upgrade. Further, passengers are willing to pay €28.13 for a sanitized seat or €17.43 for a hygiene amenity kit, compared to no hygiene services.

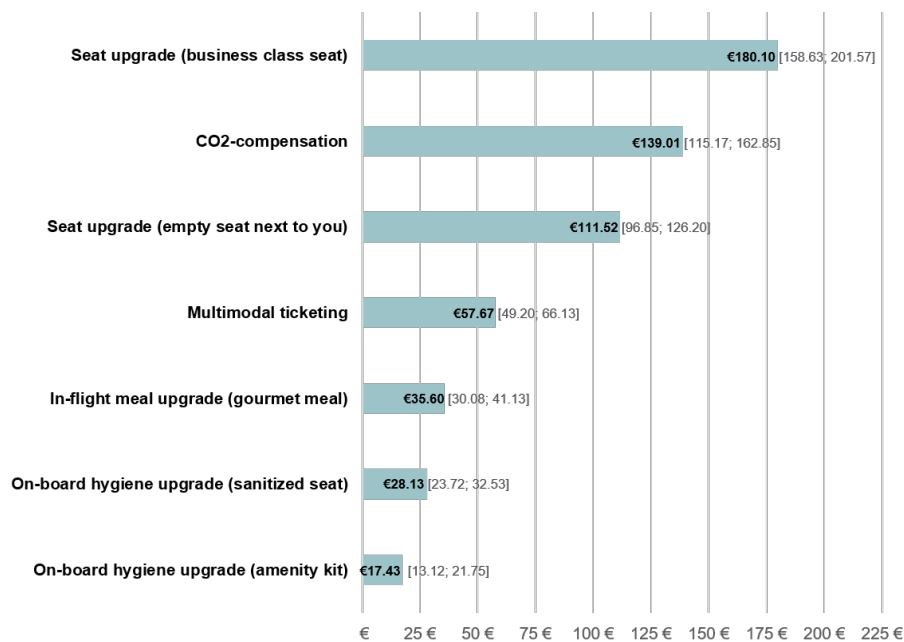


Figure 5.6: WTP values for ancillary services on a long-haul flight (medians).

Conducting the simulation scenario with three competing airlines, of which only one offers CO₂-compensation, passengers' WTP increases towards €143.40. Conducting a scenario with four competing airlines of which all offer CO₂-compensation, the passengers' WTP decreases to €119.39. Further, with the assumption of more competitors in the market, WTP decreases overall.

5.5.4.2 Bundled ancillary service upgrade packages

The trend of rebundling ancillaries and potentially targeting these bundles to passenger segments as personalized branded fares emerges (Conrady et al. 2019). Hence, the passenger demands and market potential for three examples are explored in a sensitivity analysis. Taking the experiments' attributes, three bundled upgrade packages are configured by the authors to be tested: a comfort package, an environmentally friendly green package, and a hygiene package. The green package is valuable in the light of the current sustainability debate and the drive in the aviation industry to find solutions aimed

²⁶Results are significant at an 80% confidence interval reported in Figure 5.6 as [lower 80% CI; upper 80% CI] using bootstrapping. The simulation contains extrapolated values and uses straight-line projection to estimate the level utility.

towards decarbonization. The comfort package is feasible, as comfort upgrades are shown to be highly preferred by the sample, motivating to explore differences among sub-groups. The hygiene package is developed in the light of the endemic zeitgeist and the questions of whether passengers would pay for hygiene upgrades, which could lead to an additional revenue source for airlines. The upgrade packages and related ancillary services are summarized in Table 5.5.

Table 5.5: Ancillary services bundled as packages tested in the sensitivity analysis.

Ancillary Service	Comfort Package	Green Package	Hygiene Package
CO ₂ -compensation		included	
In-flight meal upgrade	gourmet meal		
On-board hygiene upgrade			amenity kit
Seat upgrade (comfort)	business class seat		empty seat next to you
Multimodal ticketing		included	

Within this sensitivity analysis, these three packages are in competition, and the no-purchase option remains included. Perfect information, availability, and equal awareness of service among passengers are assumed. The share of preference simulation method is used again to estimate the passengers' shares at different price levels, starting with €100. Holding all else, including the price of the other packages, equal, the price-demand curves depicted in Figure 5.7 show how passengers react to an increase in the total package price. The demand is represented as the share of passengers that would choose a bundle at a given price.

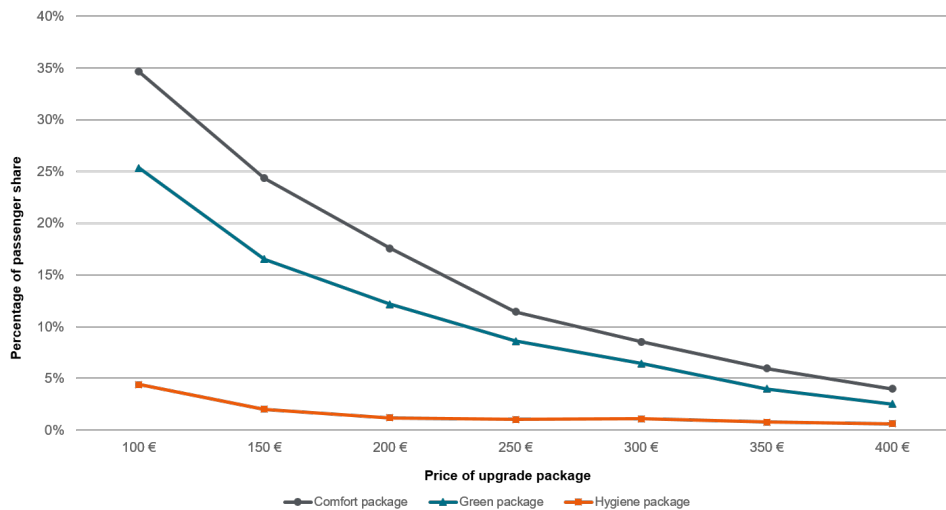


Figure 5.7: Price-demand curves for bundled ancillary service packages.

As expected, the demands for all three packages decrease with a higher price. The lowest preference is shown for the hygiene package; however, it is not zero. Around 4.5% of passengers would pay €100, and 2% would still pay €150 for the hygiene package. With the price of €200, the share drops to around 1% and remains stable at that level. The comfort package has the highest market share overall, followed by the green package. A total of 34.5% of passengers

would pay €100 for the comfort package, and 25.5% of passengers would pay €100 for the green package. Both curves converge as the price rises, but the distance between the curves decreases with a higher price. The demand curve representing the green package shows a flatter decline than the curve representing the comfort package, indicating a lower price sensitivity in passengers who pay for the green package. The demand for both packages is less than 5% at a price of €400. We further applied segmentation variables among the sample to evaluate if sub-groups prefer one package over another.

5.5.5 Bundles and passenger sub-groups

Dividing passengers along demographics and flying behavior variables (see Table 5.6), the environment-consciousness of women is again confirmed by their higher demands for the green package over all price ranges. On average, across all prices, women are willing to pay 86% more for the green package. On the other hand, men are willing to pay 195% more for the comfort package. The hygiene package preferences are equally low, showing a slightly higher preference among women.

Business passengers have a high overall willingness to pay for the comfort package. Compared to leisure passengers among all price levels, business passengers choose such a package 231% more often. The high preference among business passengers for enhanced comfort is not surprising and has been covered well in the literature (Conrady et al. 2013). Surprisingly, leisure passengers choose the green package 85% more often, most likely on personal expenses. Previous passenger surveys support the fact that, although German business passengers generally care for the environment, this awareness does not influence their travel decisions such as their mode choices (Schmalz et al. 2021a).

Within the sample, most business passengers are male and members of a FF program. Given these correlations, FFs also care more for the comfort package overall than non-members. Surprisingly, non-members have a higher market share for the green package than members, although they might fly less. Data from the Australian market confirms that business travelers and FFs are less likely to pay for carbon offsetting programs (Ritchie et al. 2021). It could also be that FFs prefer to pay for comfort due to their many journeys in order to save money. For non-members, the green package would be a rare expense on occasions that may not be as significant.

To explore the age differences among passengers, the sample is sub-divided into three generation groups: youngsters (≤ 35 years), middle-agers (36 years - 55 years), and Baby Boomers and retirees (56 years +). Most noticeable is the high market share for the green package among Baby Boomers and retirees. Around 10% of this generation would pay €400 for a green package, presenting the highest market share among all sub-groups and bundled packages in this price range (cf. Table 5.6). Youngsters and middle-agers care more for the comfort package. The hygiene package seems to be less attractive among all generations; however, 8% of the Baby Boomer & retirees would pay €100 for the hygiene package.

Overall, the sensitivity analysis reflects the importance scores explored above. Preferences differ among sub-groups. The highest market shares among all price ranges can be found for the comfort package, followed by the green package. In the *new normal*, the hygiene package does not seem to be very attractive to passengers and only interests seniors and women.

Table 5.6: Market share for packages and package prices - sub-groups.

Ancillary Service Package	Price Range of Package						
	€100	€150	€200	€250	€300	€350	€400
Gender							
Green package - male	18.1%	10.9%	8.0%	5.7%	4.3%	3.2%	2.3%
Green package - female	33.6%	23.0%	17.0%	11.9%	8.9%	5.0%	2.8%
Comfort package - male	44.9%	34.2%	26.1%	17.4%	13.0%	9.1%	5.7%
Comfort package - female	23.8%	13.9%	8.4%	5.0%	3.7%	2.6%	2.1%
Hygiene package - male	4.3%	1.8%	0.9%	0.7%	0.7%	0.5%	0.4%
Hygiene package - female	4.0%	2.1%	1.5%	1.4%	1.5%	1.1%	0.9%
Generation							
Green package - youngster	25.5%	15.4%	11.0%	7.7%	5.5%	3.1%	1.6%
Green package - middle-ager	23.8%	16.4%	12.1%	7.6%	5.1%	2.9%	1.7%
Green package - Baby Boomer & retiree	28.9%	22.5%	18.3%	15.9%	14.6%	11.8%	9.5%
Comfort package - youngster	35.9%	24.1%	15.8%	9.5%	7.2%	4.9%	3.5%
Comfort package - middle-ager	37.8%	28.2%	22.2%	15.1%	10.9%	7.4%	4.7%
Comfort package - Baby Boomer & retiree	19.9%	15.1%	13.9%	11.3%	9.2%	7.4%	4.7%
Hygiene package - youngster	3.7%	2.0%	1.3%	1.1%	1.1%	0.9%	0.8%
Hygiene package - middle-ager	4.4%	1.6%	0.7%	0.5%	0.6%	0.4%	0.3%
Hygiene package - Baby Boomer & retiree	8.0%	3.6%	2.1%	2.0%	2.2%	1.1%	0.6%
Travel purpose							
Green package - business	12.3%	8.6%	5.7%	4.3%	3.6%	3.0%	2.6%
Green package - leisure	27.0%	17.6%	13.0%	9.2%	6.8%	4.1%	2.5%
Comfort package - business	63.3%	56.4%	47.6%	34.9%	26.8%	17.2%	8.5%
Comfort package - leisure	30.9%	20.2%	13.7%	8.4%	6.2%	4.5%	3.4%
Hygiene package - business	2.5%	1.1%	0.4%	0.5%	0.7%	0.2%	0.1%
Hygiene package - leisure	4.6%	2.2%	1.3%	1.1%	1.1%	0.8%	0.7%
Frequent flyer member							
Green package - FF yes	17.8%	11.6%	8.8%	6.1%	4.7%	3.4%	2.7%
Green package - FF no	32.2%	21.0%	15.4%	11.1%	8.2%	4.7%	2.4%
Comfort package - FF yes	47.0%	36.4%	27.4%	18.4%	14.0%	9.8%	6.3%
Comfort package - FF no	22.9%	12.9%	8.2%	4.7%	3.3%	2.3%	1.8%
Hygiene package - FF yes	4.1%	2.0%	1.4%	1.3%	1.3%	1.0%	0.9%
Hygiene package - FF no	4.7%	2.1%	1.0%	0.8%	0.9%	0.6%	0.4%

5.5.6 Linear regression models

To confirm significant factors in the sample, exclude multi-correlation between the demographic variables, and make strong recommendations on the drivers of preferences, simple linear regression models are fitted in R. The regression models use the individual importance scores for the CO₂-compensation, seat upgrade, and hygiene upgrade of the 269 respondents as dependent variables (see Equations 5.4, 5.5, and 5.6).

$$\text{offset} = \beta_0 + \beta_1 \text{FF} + \beta_2 \text{gender} + \beta_3 \text{travelpurpose} + \beta_4 \text{generation} + \varepsilon \quad (5.4)$$

$$\text{hygiene} = \beta_0 + \beta_1 \text{FF} + \beta_2 \text{gender} + \beta_3 \text{travelpurpose} + \beta_4 \text{generation} + \varepsilon \quad (5.5)$$

$$\text{seat} = \beta_0 + \beta_1 \text{FF} + \beta_2 \text{gender} + \beta_3 \text{travelpurpose} + \beta_4 \text{generation} + \varepsilon \quad (5.6)$$

Results confirm the statistical significance of some demand drivers explored above. The variables *gender* ($p = .0167$) and *generation* ($p = .0171$) are confirmed as significant drivers on the individual importance of the CO₂-compensation upgrade. The variable *generation* ($p = .00124$) can be confirmed as a significant driver on the importance of the hygiene upgrade. The *travelpurpose* ($p = .00346$) and the *FF*-membership ($p < .001$) are significant drivers on the individual importance of a seat upgrade. *Gender* ($p = .06498$) is not a statistically significant driver on the individual importance of a seat (comfort) upgrade. Given the correlation between gender and travel purpose, we hence assume that the travel purpose and *FF*-membership drive the higher preference for on-board comfort more than passengers' gender.

To sum up the results, it can be seen that the upgrade price has the highest impact on passengers' choices. Although the market share is low, seniors care for the hygiene-upgrade and could open up a niche segment. Women and seniors tend more for environmentally friendly ancillaries and should be explored as green flyers. Business passengers and *FF*s care more for comfort upgrades aboard, which confirms previous research. The emergency exit seat selection does not provide value to passengers and should be disregarded as a possible service.

5.6 DISCUSSION

5.6.1 Comparing results with market prices

Comparing the WTP results from this study with available market prices in Table 5.7, German passengers correctly assess the value of the multimodal ticket upgrade covered by public transport (€58 vs. €60). Further, passengers would be willing to pay around €18 more for an in-flight meal upgrade but show a low overall preference for that ancillary service (cf. Section 5.5.2).

Table 5.7: Market simulation results compared to market prices (hygiene upgrades not on the market).

Ancillary Service	WTP Market Simulation	Market Price	Sources
CO ₂ -compensation (included)	€139	Climate projects: SAF (530KG/CO ₂ , €283) (Lufthansa Innovation Hub starting from €6 2021), (730KG/CO ₂ , €6) (Singapore Airlines 2021a), SAF: €283	energy projects (672KG/CO ₂ , €45) (atmosfair 2021) premium meal for long-haul flight offered for €18 by Condor (2021b)
In-flight meal upgrade (gourmet meal)	€36	€18	
Seat upgrade (empty seat next to you)	€112	€120 - €550 (extrapolated for long-haul from Condor)	Average price short- medium haul €40 (Condor 2021a)
Seat upgrade (business class seat)	€180	€540 - €2,502	average difference from economy premium to business: (Lufthansa 2021) (€2,502), (Singapore Airlines 2021b) (€1,410), (Delta Airlines 2021) (€772), (Condor 2021b) (€540)
Multimodal ticketing (included)	€58	€60 (return)	Rail&Fly (one-way) for 2nd class offered by Lufthansa (2021) and Condor (2021b): €30

Conversely, German passengers seem to undervalue the true costs of a business class seat, an empty neighbor seat²⁷, and CO₂-compensation with SAF. In the next section, managerial implications are retrieved from this comparison.

5.6.2 Comparing results with pre-COVID-19 times

The average utility scores must be interpreted relatively within the context of the study and the tested attributes (Orme 2019). A direct comparison of average importance scores with prior work is not possible unless an identical experiment has been already conducted pre-COVID-19, for instance, as part of a longitudinal study (Keller et al. 2021). To discuss possible preference changes due to the COVID-19 pandemic, we compare presented results with similar pre-COVID-19 choice studies from Chiambaretto (2021) and Hinnen et al. (2015), who surveyed the French and Swiss market respectively for their preferences on a long- and medium-haul flight.

Pre-COVID-19 and in the *new normal*, passengers from Germany, France, and Switzerland consider the price (ticket or upgrade price) to be the most important attribute. It has been ranked with the highest importance score among all studies, including the present choice experiment. Due to short-term work and global job loss in the *new normal*, the upgrade price might gain even higher importance within some markets, given that ancillaries are not necessary for simple air transport. Further, it is assumed that companies might want to save travel costs, and leisure passengers could have less discretionary income.

Hinnen et al. (2015) indicate that around 20% of Swiss passengers are willing to pay for CO₂-compensations. The environmental debate on decarbonization and green transformation of aviation picked up speed again during the pandemic (Gössling et al. 2021, Ringbeck and Koenig 2021), which might have influenced preferences for green ancillaries. The preference to pay for CO₂-compensation is ranked twice on the third rank, indicating that environmental

²⁷Product is currently not available for long-haul flights and the range was estimated taking extrapolated values from Condor and the total ticket price used in this study.

awareness has not necessarily increased in these transitional times. In reality, the compensation by passengers is still low (Lufthansa Innovation Hub 2021). One could assume that social desirability and the well-studied awareness-behavior gap further influenced the choice results.

It has been studied if airlines could increase yields by offering ancillary services as part of a hygiene upgrade. Results show low preference and willingness to pay for such services, despite a small market share for women and seniors. Even pre-COVID-19, the beauty amenity kit was assessed by Swiss passengers to have low overall importance. This is confirmed again by the low preference to choose the hygiene kit. Generally, amenity kits seem to be less popular, whether for disinfection or body care. It can be assumed that the hygiene awareness of passengers has not changed in the regard that additional ancillary revenue could be earned.

The in-flight meal seemed to lose relevance in the transition times. Whereas Swiss and French passengers evaluated in-flight catering as relatively relevant pre-COVID-19, it received low importance in this study. One reason for this could be that passengers are happy to fly again, given the global lockdown with decreased international air travel for a long time at a minimum, and currently, on-board catering is limited by many airlines.

Multimodal ticketing, including public transport and hotel transfer, are single ticketing services covering access and egress modes within the D2D air travel chain. The tested multimodal ticketing in this study is ranked low. One reason could be that long-haul passengers carry luggage, making it difficult to travel on public transport. Pre-COVID-19, single ticketing in the form of a hotel transfer was considered the second most important attribute; however, comparisons between these two ancillaries are limited.

5.6.3 Managerial implications

The customer value is the basis for defining the pricing position of a good or service. To set a suitable pricing strategy, it is necessary to understand the value a product or service creates, known as "*value-to-customer*" (Simon and Fassnacht 2019, p.40). Passengers are ready to fly again, and almost 60% are ready to upgrade their tickets with ancillary services. Given the COVID-19 crisis and the endemic zeitgeist, there is an even greater need to study air passengers' preferences and how they might have changed. Albers and Rundshagen (2020) argue that airlines' decision-making within the crisis will have long-term impacts. Providing a snapshot of passengers' preferences and WTP values can support airlines' product policy decisions and innovative product developments in the current times of high uncertainty and within the transition towards the *new normal*. Ultimately, results should help airlines to regain their passenger shares. Several implications can be drawn from this study:

- 1) Setting the optimal prices for high-yielding ancillary products and long-haul routes is crucial. The premium-economy class, as used in this study scenario, appeals to passengers who want greater comfort and are willing to upgrade but do not want to pay for the expensive business class. Exploring

strategies for this class is interesting for all airlines covering this route (Condor 2021b, Delta Airlines 2021, Lufthansa 2021, Singapore Airlines 2021a), but also for players such as Swiss International Air Lines, which has just started to introduce the premium-economy class on their long-haul flights (Swiss International Air Lines 2021). Results help airlines to market their ancillaries in a more passenger-centric manner, while at the same time increasing revenue by offering the right ancillary at the right price to increase passengers' buy-in. The study can support strategic management decisions regarding when to bundle or unbundle ancillaries. The differing preferences and WTP results for sub-groups also stress how vital the segmentation of passengers might be to tailor products and bundles accordingly, known as personalization (Kluge et al. 2020). For instance, although passengers show a higher preference for seat upgrades overall, the willingness to pay is lower than the actual market price estimations. To still yield this possible revenue, last-minute upgrades with free seat capacities, be it an empty neighbor seat as offered by Condor (2021a) or a free business class seat, would be possible with prior knowledge of the maximal WTP from the demand side. Such last-minute upgrade offers could be targeted to business travelers and FFs, who value on-board comfort the most. Finally, personalization can also increase customer loyalty.

2) Apart from the small market share of seniors and women, few preferences are shown for hygiene upgrades as an ancillary service, be it a sanitized seat, a hygiene amenity kit, or an empty neighbor seat, which in times of COVID-19 could also be seen as a hygiene upgrade given the created distance. In fact, the study indicates that passengers already expect a high level of on-board hygiene standards. Until herd immunity is reached globally, the aviation industry must keep investing in initiatives to keep passengers safe during travel. This hygiene factor must be fulfilled by airlines within their operations as a basis for selling additional ancillaries and increasing the overall passenger experience. As discussed above, seniors' small market shares for hygiene ancillaries could be explored in more detail to yield additional revenue with last-minute offers or personalization strategies.

3) Creating a sustainable aviation system is high on the agenda of airlines, airports, and airport feeders (Schmalz et al. 2021d). Globally, 75% of aviation experts would like to see the COVID-19 induced crisis as an opportunity to push towards a green transition within aviation (Ringbeck and Koenig 2021). The IATA (4.10.2021) recently committed to achieving net-zero carbon emissions by 2050 within the industry. Experts assess market-based measures such as offsetting as a short-term lever with relative effectiveness of 28% emission reduction until 2030 (Ringbeck and Koenig 2021). According to the Destination 2050 report, however, the greatest share towards reaching long-term decarbonization until 2050 lies in SAF (van der Sman et al. 2020). Although offsetting with SAF is more expensive than climate projects (cf. Table 5.7), the long-term effectiveness is higher, especially on long-haul flights given longer flight times and trip distances. Airlines' booking pages are still too revenue-oriented. To truly create a more sustainable aviation system, we urge airlines to include CO₂-compensation options directly and subliminally within the booking pro-

cess; this is compared to the current situation, in which passengers often need to actively open a new web page and manually calculate their emissions (atmosfair 2021, Lufthansa Innovation Hub 2021, Singapore Airlines 2021a). Passengers should be educated about the true environmental costs of their flights at a glance and be shown how much CO₂ and other emissions are generated per person and booked seat. To create transparency, these numbers might further need comparisons with other means of transport and sources of emissions from our everyday lives. Emissions could be calculated for the entire D2D air travel chain, as done by EcoPassenger (2020), also nudging passengers towards buying access and egress services (multimodal ticketing) and hence additional ancillaries via the airline website. Airlines might consider green nudging of specific passenger segments towards offsetting, such as women and senior passengers who show the strongest preferences. Further, compensations by airlines may become obligatory, leading to the question of how much of that cost will be handed over to the passenger. WTP results from this study can help to set the optimal pricing for airlines to stay in the market and clearly show the higher importance of offsetting from the passenger demand side.

5.6.4 *Limitations and further research*

The presented experiment assumes perfect market conditions and information on the consumer side, which is unrealistic. As explored in the RUT by McFadden (1974), there is also the unknown component determining consumers' utility, which we were not able to detect within the experiment.

Passengers were surveyed using a convenient sample, and results are not transferable to the general population or non-fliers in Germany. Results are applicable to the developed scenario of long-haul, one-way air trips with limited transferability to short- or medium-haul flights.

The sample size could be increased to reach 300 respondents, as proposed by Orme (2019). As done in other studies (Ritchie et al. 2021), it would have been possible to obtain a more representative sample using a professional panel company. However, this requires a higher budget. Another way to increase the sample size would be a data partnership, such as with an airline or airport. The study can be replicated leveraging such collaborations or a professional panel.

The success of a CBC depends heavily on the selected attributes and levels. Missing out relevant factors might impair the results. As elaborated by former studies (König et al. 2018), we believe that through a comprehensive literature review, expert workshops, and interviews, we have selected the most essential and valid attributes for the study design. However, given the current uncertainty due to COVID-19, the study outcome must be interpreted with caution. Further, there is a reliance on passengers answering the questionnaire according to their actual and true beliefs. We have limited knowledge of the comprehension rate (i.e., if respondents fully understood the travel scenario, the attributes, and the corresponding levels). Perception of what is meant by premium-economy class within the scenario could also differ, as various airlines offer this booking class.

Social biases could have influenced the choice behavior of respondents. Presenting the fixed order of the upgrade price in the choice set's design can lead to order biases (Sawtooth Software 2017). We also received some feedback that the choice set design was too complex and took too long to fill out the survey. Other respondents would have preferred to evaluate each ancillary service individually instead of choosing between upgrade packages.

It will be interesting to explore how many passengers pay for CO₂-compensation and what latent factors might influence them to translate their environmental awareness into an actual behavior change. One possible way would be a second survey in which respondents answer the questionnaire from the perspective of a friend or neighbor. In this way, the user's preferences are not queried but rather the most probable preferences, which might provide more realistic insights. Passenger segments could be explored in-depth, such as with latent clustering, supporting further personalization and ancillary bundling.

5.7 CONCLUSION

The COVID-19 crisis creates uncertainty and disrupts the aviation industry. The question arises of what consumer preferences within the *new normal* look like, especially regarding air travel. The present study filled this research gap by conducting a CBC with 269 German passengers for a long-haul flight, testing their preferences for ancillary (non-ticket) services as a possible flight upgrade. The research objectives were to identify passengers' preferences for ancillary services, examine the effect of demographics and travel behavior variables on choices, and quantify WTP values. The choice set depicted four alternative ancillary service upgrade packages, which incorporated combinations of the total price, CO₂-compensation, an in-flight meal upgrade, an on-board hygiene upgrade, seat upgrades for greater comfort, and single multimodal ticketing for access and egress to the airport. A HB MNL model was utilized to analyze the choice data. Linear regressions supported the analysis.

Results reveal that the overall upgrade price still has the highest impact on passengers' choices. In this transitional time, higher preferences are shown for upgrading with CO₂-compensation and choosing comfort upgrades. Low overall preference is indicated for an in-flight meal and multimodal ticket upgrade. High hygiene standards on board are considered as a given by most passengers. Although the market share is low, seniors care for the hygiene upgrade services, and this suggests a potential niche segment. Women and seniors tend more for environmentally friendly ancillaries and should be explored as potential green flyers. It is positive that there is a high willingness to compensate, but the real costs of an effective SAF-offsetting program for a long-haul flight seem to be underestimated. Business passengers and FFs care more for comfort upgrades aboard, which confirms previous research.

These insights offer airlines a snapshot of passengers' preferences in the uncertain times of the *new normal*. Results can be particularly valuable for new approaches of ancillary service pricing, developing personalized bundles, and yielding last-minute revenue options.

Summary and outlook

6.1 CONCLUSION

D2D air travel is gaining momentum for TSPs such as airlines, airports, and airport feeders. Researchers and the mobility industry broaden their scope to look beyond only one mode; instead, they integrate the entire intermodal travel chain from origin to the final destination. The doctoral thesis at hand aimed to *understand trends in the context of D2D air travel in the European market, incorporating both supply and demand*. To explore this objective, the research endeavored to apply three different methods for trend identification (Chapter 2 and Chapter 3), a trend analysis that studied supply (Chapter 4), and a trend analysis that examined demand (Chapter 5).

Within Chapter 2, a Delphi-based scenario study was conducted to identify trends and scenarios of future D2D travel in 2035 on long-haul flights. The Delphi technique structures the communication between experts to answer current and future-related questions. 38 experts representing different TSPs and scholars were surveyed, creating the desired intermodal scope. Group results were returned to each participant in a second survey round, providing the opportunity to adapt their assessments based on new insights that could have been gained from the group's response. Consensus or disagreement among the panelists regarding possible future projections evolved. Each projection was discussed within the respective theoretical background in the literature. Results shed light on how the future of D2D air travel might look in 2035 (Q1). Digitalization and personalization will be the main drivers, and passengers might want to use their travel time in a value-added way. Environmentally friendly travel products are considered desirable but only somewhat probable by 2035. Passenger type, age, origins, and budget will still be influential factors.

Using HC, three trend scenarios depicting possible futures for 2035 focused on the European market and long-haul flights were developed: (1) personalized D2D travel, (2) integrated D2D travel, and (3) the game changer. The game changer is the disruptive black swan scenario that contains an alternative future for 2035 towards a full monetization of the cabin by tech companies, downgrading the supply side to pure logistic providers, and changing revenue streams for TSPs.

Chapter 4 examined whether European TSPs (the suppliers) already consider D2D air travel trends as relevant, based on their communications in corporate reports (Q2). To understand trends in-depth and to identify in which way the industry is already acting upon these, data science techniques offer new approaches. Classes were defined a priori and developed from trend hypotheses based on the results of Chapter 2 and a literature review of prevailing research. Two prototype models were developed: a dictionary-based classifier and a su-

pervised learning model using the NB and linear SVM classifiers. Fifty-two objects of analysis (annual corporate reports and sustainability reports) were gathered and analyzed. The model performances were compared and the final model output was used for an in-depth discussion on TSP-level and to build three trend clusters.

The study reveals which trends have a higher, medium, or lower relevance as regards to supply. TSPs consider environmentally friendly air transport and related products as highly relevant, while disruption management, leveraging passengers' data, and improving airport feeder traffic through new mobility concepts are seen to be of medium relevance. The Delphi study in Chapter 2 showed that environmentally friendly D2D travel products are assessed as being somewhat probable by 2035; however, they are a key aspect within today's communication efforts from TSPs.

Chapter 5 utilized the CBC to examine preferences of passengers (the demand side) for ancillary services within the transition to the *new normal* on a long-haul flight (Q3). This survey-based technique detects stated choices of consumers for product options by developing multi-attribute product profiles and letting respondents choose the one that provides them the highest utility. The choice set depicted four alternative flight upgrade packages, which incorporated combinations of the total upgrade price, a CO₂-compensation, an in-flight meal, on-board hygiene upgrades, seat (comfort) upgrades, and a multimodal ticket. 269 German business and leisure passengers were surveyed and provided a snapshot of the current situation in the market. A HB MNL model and linear regressions were utilized to analyze the choice data.

Results reveal that the overall upgrade price still has the highest impact on passengers' choices. Higher preferences are shown for upgrading with CO₂-compensation and choosing comfort upgrades. Low overall preference is indicated for an in-flight meal and a multimodal ticket. High hygiene standards on board are considered as a given by most passengers.

Senior passengers care the most for the hygiene upgrade services, suggesting a potential niche segment. Business passengers and FFs care more for comfort upgrades aboard, which confirms previous research. Women and seniors tend more for environmentally friendly ancillaries and should be explored as potential green flyers. It is positive that there is a high willingness to compensate, but the real costs of an effective SAF-offsetting program for a long-haul flight seem to be underestimated by the demand side.

6.2 CONTRIBUTION TO THE LITERATURE

Given the high relevance of D2D air travel, little has been published within the transport-related scientific community; however, publications have increased over the past few years. This thesis contributes to this growing field of research. The novel scope of D2D air travel was first applied to the Delphi technique, providing expert-confirmed trends and three future scenarios. Furthermore, this thesis provided an in-depth and step-by-step discussion of conducting a Delphi-based scenario study, which has already been the foundation for an-

other technical paper (Beiderbeck et al. 2021). The developed text-classification models in Chapter 4 enabled cheaper and quicker analysis of companies' textual data and allowed the relevance of this scope to be assessed. This innovative approach and the prototype models are applicable to other research questions, such as market studies and finance-related projects. Finally, results from Chapter 5 provided an indicator about passengers' preferences within the transition phase towards the *new normal* and contributed to the growing research field on COVID-19-related trends.

Overall, this thesis has aimed to provide a methodological approach on how to analyze future mobility trends using a mixed-method framework. The emerging scope of D2D air travel was taken as an example, but the approach might be suitable for and transferable to a variety of future-related questions. In particular, trends that have just emerged, such as advancements in technology or unforeseen and highly disruptive trends, and of which historical data is scarce or difficult to collect, might be suitable. In phase one, the Delphi technique allows a suitable starting point for analyzing future trends in an exploratory way using input from subject matter experts. In phase two, supervised and unsupervised models allow trend detection and hypotheses testing in a more systematic way. In phase three, demand is analyzed in more detail, including the passengers' view as the user of air transport and overall mobility system. Hypotheses development, expert interviews, literature reviews, and expert workshops support all three phases.

6.3 MANAGERIAL RECOMMENDATIONS

This thesis offers managerial insights for airports, airlines, and airport feeders that seek to become real D2D mobility suppliers. Detecting trends and developing plausible future scenarios create a better understanding of what future air travel from an intermodal perspective might look like. Such insights support strategy- and decision-making as well as pricing and product development, for instance. The D2D air travel scope has shown to be a relevant perspective that is gaining momentum. Improving the travel experience along the D2D air-travel value chain, such as offering integrated and personalized mobility, establishing partnerships and aligning services, help to meet the needs of demand, and increase market share and ancillary revenue. Given the current COVID-19 crisis in the air transport market, the transition towards the *new normal*, and the threat of tech companies to transform themselves into real intermodal mobility providers and cover the interface to passengers, these efforts have become even more relevant.

It has been shown that passengers want to spend their travel time in a value-added way. In that regard, passenger groups and their differentiated needs open up business opportunities for targeted ancillary services and setting optimal pricing strategies. The results of this thesis show that passengers' preferences in the *new normal* world still differ between age groups, travel purpose, the propensity to fly, and gender. Mobility companies are advised to adopt measures aimed at personalization and digitalization, create personalized jour-

ney experiences, and think about products and services within the *new normal* and in terms of hygiene factors that need to be fulfilled.

The biggest challenge for intermodal air travel is to tackle the climate crisis. Creating a sustainable aviation system is already high on the agenda of TSPs. At the same time, D2D air travel should be inclusive, socially compatible, and cover rural areas. Next to technical solutions, stakeholders are called upon to provide environmentally friendly transport and ancillary services, be it an effective compensation scheme leveraging SAF, multimodal tickets that include public transport, aircraft sharing concepts, or longer flying times on specific routes to reduce emissions. Like-minded passenger segments with preferences towards environment-friendly air travel (green flyers) are discovered in this thesis. They now need to be nudged towards such services and operational solutions (green nudging).

6.4 LIMITATIONS AND FUTURE RESEARCH

There is ample room for further research on trends around D2D air travel. This research endeavor focuses on the European market, which is mature and highly developed. Due to cultural, political, technological, and economic differences, results are not easily transferable to other markets. Further research is encouraged exploring regions like Asia, Africa, and North America. The CBC in Chapter 5 focuses on German passengers. The choice experiment needs to be replicated in more countries to cover the European market.

Second, within the next few years, the definition of D2D air travel as presented might evolve. Driven by digital transformation, data disposal, new collaborations, and emerging customer needs, aspects such as hospitality, entertainment, shopping, and recreation could become part of the travel chain definition and broaden its scope. TSPs might not just seek to become intermodal mobility platforms, especially given the development of MaaS, but lifestyle companies covering services and products within every aspect of our lives. This also requires a mindset shift in the research community.

The field of data analytics, and, in particular, of artificial intelligence (AI), holds ample room for further research and practical applications. There is much potential to apply machine learning models for trend detection and trend testing, for instance. The prototype models presented in Chapter 4 allow a comparison of classification models and their methodological advantages and disadvantages. Further research is encouraged to advance these models, given rapid technological developments, open access to codes and software, and improvements in computing power available to researchers today. Data sharing and data availability - while ensuring the privacy of passengers - will be the key to harness to the full potential of data analytics.

To conclude, the topic of future D2D air travel provides ample room for further research, and the great business potential for TSPs cannot be dismissed, be it for improving the overall travel experience, providing intermodal and personalizing services in collaboration with new partners, creating a more environmentally friendly transport system, or expanding additional ancillary revenues.

Appendix 1b

A.1 TABLES

Table A.1: Overview lessons learned and technical publications on the Delphi technique.

Author(s) (Year)	Journal	Title
Bolger and Wright (2011)	Technological Forecasting & Social Change	Improving the Delphi process: Lessons from social psychological research
Frewer et al. (2011)	Technological Forecasting & Social Change	The use of Delphi methodology in agrifood policy development: some lessons learned
Goluchowicz and Blind (2011)	Technological Forecasting & Social Change	Identification of future fields of standardisation: An explorative application of the Delphi methodology
Hasson and Keeney (2011)	Technological Forecasting & Social Change	Enhancing rigour in the Delphi technique research
Hussler et al. (2011)	Technological Forecasting & Social Change	Is diversity in Delphi panelist groups useful? Evidence from a French forecasting exercise on the future of nuclear energy
Nowack et al. (2011)	Technological Forecasting & Social Change	Review of Delphi-based scenario studies: Quality and design considerations
Zimmermann et al. (2012)	Technological Forecasting & Social Change	Integrating Delphi and participatory backcasting in pursuit of trustworthiness - the case of electric mobility in Germany
Förster and von Gracht (2014)	Technological Forecasting & Social Change	Assessing Delphi panel composition for strategic foresight – A comparison of panels based on company-internal and external participants
Gray and Morris (2016)	Issues in Information Systems	The Delphi Technique: Lessons Learned from a first time researcher
Jünger et al. (2017)	Palliative Medicine	Guidance on Conducting and REporting DELphi Studies (CREDES) in palliative care: Recommendations based on a methodological systematic review
Hirschhorn (2019)	International Journal of Social Research Methodology	Reflections on the application of the Delphi method: lessons from a case in public transport research
Belton et al. (2019)	Technological Forecasting & Social Change	Improving the practical application of the Delphi method in group-based judgment: A six-step prescription for a well-founded and defensible process
Markmann et al. (2021)	Futures & Foresight Science	Improving the question formulation in Delphi-like surveys: Analysis of the effects of abstract language and amount of information on response behavior
Mauksch et al. (2020)	Technological Forecasting & Social Change	Who is an expert for foresight? A review of identification methods

Table A.2: Overview top five cited papers across disciplines (Scopus search with keyword "Delphi" November 2020).

Discipline	Author(s) (Year)	Journal	Title	Cited by
Healthcare^a	Singer et al. (2016)	JAMA - Journal of the American Medical Association	The third international consensus definitions for sepsis and septic shock (sepsis-3)	6063
	Siang (2010)	European Journal of Epidemiology	Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses	5420
	Cummings et al. (1994)	Neurology	The neuropsychiatric inventory: Comprehensive assessment of psychopathology in dementia	5294
	Palisano et al. (1997)	Developmental Medicine and Child Neurology	Development and reliability of a system to classify gross motor function in children with cerebral palsy	3893
	Dellinger et al. (2008)	Critical Care Medicine	Surviving sepsis campaign: International guidelines for management of severe sepsis and septic shock: 2008	3743
Engineering	Zhang et al. (2008)	Osteoarthritis and Cartilage	OARSI recommendations for the management of hip and knee osteoarthritis, Part II: OARSI evidence-based, expert consensus guidelines	1813
	McAlindon et al. (2014)	Osteoarthritis and Cartilage	OARSI guidelines for the non-surgical management of knee osteoarthritis	1440
	Schaeff et al. (2006)	European Physical Journal C	Search for neutral MSSM Higgs bosons at LEP	581
	Zhang et al. (2007)	Osteoarthritis and Cartilage	OARSI recommendations for the management of hip and knee osteoarthritis, Part I: Critical appraisal of existing treatment guidelines and systematic review of current research evidence	565
	Achanga et al. (2006)	Journal of Manufacturing Technology Management	Practical Assessment, Research and Evaluation	546
Social Science	Hsu and Sandford (2007)	Practical Assessment, Research and Evaluation	The Delphi technique: Making sense consensus	1965
	Brooks et al. (2005)	Global Environmental Change	The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation	996
	Deardorff (2006)	Journal of Studies in International Education	Identification and assessment of intercultural competence as a student outcome of internationalization	734
	Osborne et al. (2003)	Journal of Research in Science Teaching	What "ideas-about-science" should be taught in school science? A delphi study of the expert community	515
	Choi and Sirakaya (2006)	Tourism Management	Sustainability indicators for managing community tourism	440
Business Research^b	Okoli and Pawlowski (2004)	Information and Management	The Delphi method as a research tool: An example, design considerations and applications	1687
	Rowe and Wright (1999)	International Journal of Forecasting	The Delphi technique as a forecasting tool: Issues and analysis	1108
	Schmidt et al. (2001)	Journal of Management Information Systems	Identifying software project risks: An international Delphi study	769
	Landeta (2006)	Technological Forecasting & Social Change	Current validity of the Delphi method in social sciences	567
	Gartner (1999)	Journal of Business Venturing	What are we talking about when we talk about entrepreneurship?	559
Computer Science	Schmidt et al. (2001)	Journal of Management Information Systems	Identifying software project risks: An international Delphi study	769
	Lee et al. (2009)	Expert Systems with Applications	A green supplier selection model for high-tech industry	477
	Brancheau and Wetherbe (1987)	MIS Quarterly: Management Information Systems	Key issues in information systems management	475
	Brancheau et al. (1996)	MIS Quarterly: Management Information Systems	Key issues in information systems management: 1994-95 SIM delphi results	470
	Niederman et al. (1991)	MIS Quarterly: Management Information Systems	Information systems management issues for the 1990s	452
Environmen. Science	Brooks et al. (2005)	Global Environmental Change	The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation	996
	Landrigan et al. (2002)	Environmental Health Perspectives	Environmental pollutants and disease in American children: Estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities	339
	Kannan et al. (2002)	Environmental Science and Technology	Perfluorooctanesulfonate and related fluorinated hydrocarbons in marine mammals, fishes, and birds from coasts of the Baltic and the Mediterranean Seas	336
	Seuring and Müller (2008)	Business Strategy and the Environment	Core issues in sustainable supply chain management - A Delphi study	316
	James et al. (2009)	Urban Forestry and Urban Greening	Towards an integrated understanding of green space in the European built environment	236
Physics & Astronomy	Amaldi et al. (1991)	Physics Letters B	Comparison of grand unified theories with electroweak and strong coupling constants measured at LEP	1218
	Heister et al. (2003)	Physics Letters, Section B: Nuclear Elementary Particle and High-Energy Physics	Search for the standard model higgs boson at LEP	989
	Bagger et al. (2006)	Physics Reports	Precision electroweak measurements on the Z-resonance	981
	Schaeff et al. (2006)	European Physical Journal C	Search for neutral MSSM Higgs bosons at LEP	581
	Abreu et al. (1996)	Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment	Performance of the DELPHI detector	309
Biochemistry, Genetics & Molecular Biology	Jordan et al. (2003)	Annals of the Rheumatic Diseases	EULAR Recommendations 2003: An evidence based approach to the management of knee osteoarthritis: Report of a Task Force of the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCI/IT)	1468
	Smolen et al. (2008)	Annals of the Rheumatic Diseases	Treating rheumatoid arthritis to target: Recommendations of an international task force	1355
	Smolen et al. (2008)	Annals of the Rheumatic Diseases	EULAR recommendations for the management of rheumatoid arthritis with synthetic and biological disease-modifying antirheumatic drugs	1233
	O'mahony et al. (2015)	Age and Ageing	STOPP/START criteria for potentially inappropriate prescribing in older people: Version 2	903
	Zhang et al. (2006)	Annals of the Rheumatic Diseases	EULAR evidence based recommendations for gout. Part II: Management. Report of a task force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCI/IT)	901

^aHealthcare includes medicine, nursing and health professions according to Scopus subject areas

^bBusiness research includes business, management, and accounting according to Scopus subject areas

Table A.3: Interview guide: expert interviews on the future of mobility.

Section	Guiding Questions
Preface: three main objectives of the interviews	<ol style="list-style-type: none"> 1.Characteristics of current & future passengers 2.Insights into methods used to understand the mobility market 3.The future of mobility: ways to travel, challenges, future modes of transport, need for action and investments
A. Generals	<p>Introduction (project, data protection, aim of interview)</p> <p>Company name and department/division of interviewee & area of expertise of interviewee</p>
B. Characterizing current & future customer markets	<p>Why is it important to have knowledge about passengers?</p> <p>What are expectations, needs and requirements of customers/passengers?</p> <p>Are any regulations, local or national government planning (current and future) might affect expectations, needs and requirements of mobility passengers?</p> <p>What methodologies are commonly used in the mobility sector to gain information about passengers (such as demographic information, travel or booking behavior)?</p> <p>How can we gain information about how passenger types, booking and traveling behavior is going to change?</p> <p>What are challenges or drawbacks when carrying out research on passengers?</p>
C. Future of mobility	<p>How are we going to travel in the future (in 2035 and 2050)?</p> <p>What are the modes of the future?</p> <p>What are major challenges facing the overall transport system (e.g., aging population, digitalization)?</p> <p>Are there any effects on current business models for the future?</p> <p>What are the jobs expected to emerge, change or disappear in the future transport workforce?</p> <p>Where is further research, action or investment necessary for improvement of the European transport system?</p>
D. Wrap up	<p>Is there anything you would like to add at this point, which has not been addressed here but you consider as essential when thinking about the topics above?</p>

A.2 FIGURES



Delphi Study on future D2D passengers (1st round)

Tackling the future: welcome to 2035!

This survey is concerned with **trends and future passenger needs** along the **door-to-door (D2D)** travel chain of **long-haul air travel** in **2035** (both in the context of business and leisure trips). We would like to take this long-term perspective on **European travelers**.

Assumptions

For the future European market, we consider a GDP growth at +1.8% per year until 2035. Total European air travel demand (in RPK) is expected to grow at +3.1% per year until 2035¹. We expect the overall European population to stay stable² (no strong growth or decrease) and we do not expect any financial or medical crises nor terroristic attacks. Please also note that we do not consider everyday mobility, only D2D mobility from the perspective of long-haul air travel.

Questionnaire

There are no right or wrong answers. The future statements hereafter are projections that you should kindly evaluate from **your point of view representing your company, consultancy or research facility**. Please fill out each question and choose only one box per row. For each future projection, please evaluate the following:

- Probability:** Please evaluate how likely or probable the statement is.
- Impact:** In case of occurrence, please evaluate the impact of the statement on D2D mobility offers.
- Desirability:** Please evaluate how desirable the statement is for your company (or in case, you are a consultant, expert or researcher, for overall D2D mobility offers)
- Personal view:** Please provide a short written justification for each of your answers.

Contact

If you have any questions, please do not hesitate to contact us:

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¹ Adapted from Airbus (2018), *Global Market Forecast 2018 – 2037*.

² Adapted from UN (2017), *World Population Prospects: The 2017 Revision*.

Figure A.1: Extract of Delphi questionnaire used in first round (p.1).



Part 1: Survey (17 questions)

1. In 2035, passengers will increasingly demand personalized D2D journeys (on-demand, flexible & adapted towards personal preferences).

Probability	Not probable <input type="checkbox"/>	Improbable <input type="checkbox"/>	Somewhat improbable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat probable <input type="checkbox"/>	Probable <input type="checkbox"/>	Very probable <input type="checkbox"/>
Impact	Very weak <input type="checkbox"/>	Weak <input type="checkbox"/>	Somewhat weak <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat strong <input type="checkbox"/>	Strong <input type="checkbox"/>	Very strong <input type="checkbox"/>
Desirability	Very undesirable <input type="checkbox"/>	Undesirable <input type="checkbox"/>	Somewhat undesirable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat desirable <input type="checkbox"/>	Desirable <input type="checkbox"/>	Very desirable <input type="checkbox"/>
Personal view							

2. In 2035, age will not define passengers' needs that much anymore.

Probability	Not probable <input type="checkbox"/>	Improbable <input type="checkbox"/>	Somewhat improbable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat probable <input type="checkbox"/>	Probable <input type="checkbox"/>	Very probable <input type="checkbox"/>
Impact	Very weak <input type="checkbox"/>	Weak <input type="checkbox"/>	Somewhat weak <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat strong <input type="checkbox"/>	Strong <input type="checkbox"/>	Very strong <input type="checkbox"/>
Desirability	Very undesirable <input type="checkbox"/>	Undesirable <input type="checkbox"/>	Somewhat undesirable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat desirable <input type="checkbox"/>	Desirable <input type="checkbox"/>	Very desirable <input type="checkbox"/>
Personal view							

3. In 2035, travel preferences within D2D journeys will increasingly differ by gender.

Probability	Not probable <input type="checkbox"/>	Improbable <input type="checkbox"/>	Somewhat improbable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat probable <input type="checkbox"/>	Probable <input type="checkbox"/>	Very probable <input type="checkbox"/>
Impact	Very weak <input type="checkbox"/>	Weak <input type="checkbox"/>	Somewhat weak <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat strong <input type="checkbox"/>	Strong <input type="checkbox"/>	Very strong <input type="checkbox"/>
Desirability	Very undesirable <input type="checkbox"/>	Undesirable <input type="checkbox"/>	Somewhat undesirable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat desirable <input type="checkbox"/>	Desirable <input type="checkbox"/>	Very desirable <input type="checkbox"/>
Personal view							

Figure A.2: Extract of Delphi questionnaire used in first round (p.2).



16. In 2035, airlines, public transport, and airports will mainly focus on providing transport services. Tech companies will take over additional services offered to passengers (such as on-board shopping, entertainment, etc.).

Probability	Not probable <input type="checkbox"/>	Improbable <input type="checkbox"/>	Somewhat improbable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat probable <input type="checkbox"/>	Probable <input type="checkbox"/>	Very probable <input type="checkbox"/>
Impact	Very weak <input type="checkbox"/>	Weak <input type="checkbox"/>	Somewhat weak <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat strong <input type="checkbox"/>	Strong <input type="checkbox"/>	Very strong <input type="checkbox"/>
Desirability	Very undesirable <input type="checkbox"/>	Undesirable <input type="checkbox"/>	Somewhat undesirable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat desirable <input type="checkbox"/>	Desirable <input type="checkbox"/>	Very desirable <input type="checkbox"/>
Personal view							

17. In 2035, political frameworks will support integrated, seamless D2D mobility.

Probability	Not probable <input type="checkbox"/>	Improbable <input type="checkbox"/>	Somewhat improbable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat probable <input type="checkbox"/>	Probable <input type="checkbox"/>	Very probable <input type="checkbox"/>
Impact	Very weak <input type="checkbox"/>	Weak <input type="checkbox"/>	Somewhat weak <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat strong <input type="checkbox"/>	Strong <input type="checkbox"/>	Very strong <input type="checkbox"/>
Desirability	Very undesirable <input type="checkbox"/>	Undesirable <input type="checkbox"/>	Somewhat undesirable <input type="checkbox"/>	Neutral <input type="checkbox"/>	Somewhat desirable <input type="checkbox"/>	Desirable <input type="checkbox"/>	Very desirable <input type="checkbox"/>
Personal view							

Part 2: Personal Details

- Gender** Female Male
- Industry / mode (most applicable)** Airport Airline Public transport
 Supplier Self-employed
 Futurist Research facility / University
 Other:

Position

Years of experience in mobility sector

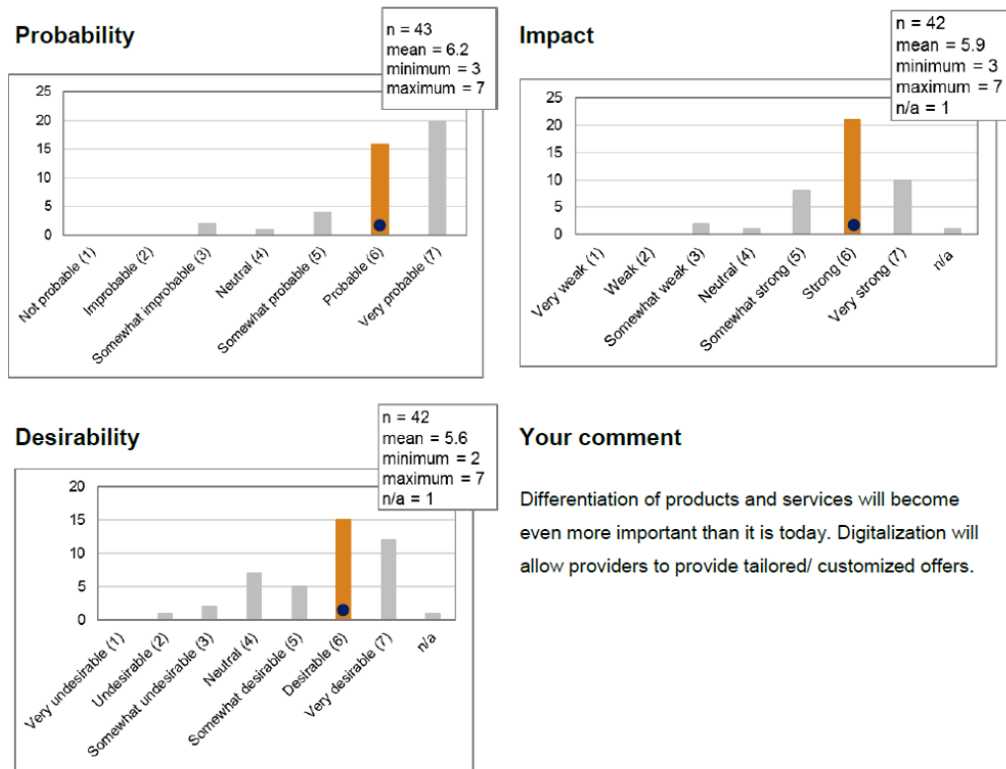
E-mail address

Expertise: How would you assess your expertise for answering these questions?	Very low <input type="checkbox"/>	Low <input type="checkbox"/>	Basic <input type="checkbox"/>	High <input type="checkbox"/>	Very high <input type="checkbox"/>
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Thank you very much for your participation! After evaluating this first-round questionnaire, the results and the second-round questionnaire will send to you by mid November 2018.

Figure A.3: Extract of Delphi questionnaire used in first round (p.7).

1. In 2035, passengers will increasingly demand personalized D2D journeys (on-demand, flexible & adapted towards personal preferences).



Aggregated opinions of experts

Comments enabling statement	Comments inhibiting statement
Overall trend of personalization and individualization, observable in other sectors today, already influencing travel, and will continue.	Too complex (technology, planning, implementation) and expensive to achieve by 2035.
Digitalization, new technical solutions and new forms of mobility (e.g. Urban Air Mobility) will enable this statement and makes it easier to cater for different needs.	Personalized travel also induces an explosion of traffic and will further congest infrastructures and pollute the environment, unless all stakeholders tackle the problem intelligently.
Since value of time has been increasing, shorter D2D journeys will be more desirable. D2D mobility would also increase comfort of passengers.	For the European market, adoption might be slower due to automotive culture and installed infrastructure.
Public transportation is becoming more individual and individual transportation is becoming more public.	Passengers would probably prefer it, but to provide this will include major invests into current IT technologies and airline processes.
The offering will increasingly shape the demand. Mobility providers need to offer customized services, on-board and in-flight products and IFE.	Long haul air travel will still be a relative niche, and personalized D2D will not be as important as on short hauls as people will be willing to accept buffer times.
Personalization will have very positive results to transport stakeholders, as they finally know the customers destinations, routings and service expectations enhancing their ops as well.	In the future, it may be easy to combine different services for passengers so that the value-added of integrated services may be small for the majority of travelers.
Personalization will become one of the key differentiators across mobility and especially for the premium D2D mobility offers.	More relevant for business travelers (and wealthy private travelers) than for the majority of other travelers.

Figure A.4: Extract of Delphi questionnaire used in second round (projection 1).

A.3 R CODE

Code for HC in R (version 4.0.1 (2020-06-06) and RStudio version 1.3.959-1 (2020-05-22))

```
1 # Required packages
  require(readxl)
  require(stats)
  require(base)
  require(graphics)
6
  # upload data into R
  ## Create subset for clustering and look at structure
    DataClust = data_file
    head(DataClust)
11
  ## Hierarchical clustering (HC) using Ward's method. Two ward clustering;
    only ward.D2 uses ward (1963) hence, this is used for the Delphi study
    (but cluster results are both same in our study)

  ## Compute distance matrix
    Delphi_distances <- dist(DataClust, method="euclidean")
16
  ## Conduct HC using ward's method (ward.D2)
  ## Set seed to make your results replicable
    set.seed(42)
    res.hc <- hclust(Delphi_distances, method="ward.D2")
21
    res.hc$centers
    str(res.hc)

  ## Cut tree into 3 groups
    grp <- cutree(res.hc, k = 3)
26
  ## Visualize in dendrogram
    plot(res.hc,
          cex = 0.75,
          ylab = "Height",
31
          xlab = "Projections",
          labels = DataClust$Consensus,
          main = "Hierarchical Clustering",
          sub = "ward.D2",
          hang = -0.9)
36
  ## Plot tree (if you want, save as picture)
    rect.hclust(res.hc,
                k = 3,
                border = 2:5)
41
  ## In case you need help, use help() function
  help("hclust")
  help("dist")
  help("cutree")
46
  help("plot")
```

Appendix 2

B.1 TABLES

Table B.1: Top 30 European airports retrieved from OAG (2018) based on total planned seat capacity (departure and arrival); 22 airports included in sample; 30 airports included as keywords.

#	Airport Name (Domicile Country)	In Sample	Total Seat Capacity
1	London Heathrow Apt (UK)	x	99.805.194
2	Frankfurt Intl. Apt (DE)		88.868.689
3	Paris Charles de Gaulle Apt (FR)	x	86.530.078
4	Istanbul Ataturk Apt (TR)	x	83.343.911
5	Amsterdam Apt (NL)	x	81.387.234
6	Madrid Adolfo Suarez-Barajas Apt (ES)	x	69.021.727
7	Munich Intl. Airport (DE)		61.580.389
8	Barcelona Apt (ES)	x	60.379.660
9	Moscow Sheremetyevo Intl. Apt (RU)	x	55.283.585
10	Rome Fiumicino Apt (IT)	x	55.270.558
11	London Gatwick Apt (UK)	x	52.237.947
12	Zurich Apt (CH)	x	41.319.089
13	Paris Orly Apt (FR)	x	41.179.843
14	Istanbul Sabiha Gokcen Apt (RU)		39.638.741
15	Copenhagen Kastrup Apt (DK)	x	39.080.691
16	Oslo Gardermoen Apt (NO)	x	38.298.280
17	Vienna Intl. Apt (AT)	x	35.700.301
18	Stockholm Arlanda Apt (SE)	x	35.630.452
19	Lisbon Apt (PT)	x	34.912.145
20	Palma de Mallorca (ES)	x	33.820.858
21	Dublin Apt (IE)	x	33.294.172
22	Manchester (GB) Apt (UK)	x	32.975.110
23	Moscow Domodedovo Apt (RU)		32.585.070
24	Brussels Apt (BE)	x	31.936.415
25	London Stansted Apt (UK)	x	31.884.388
26	Duesseldorf Intl. Apt (DE)	x	31.614.106
27	Milan Malpensa Apt (IT)		31.288.309
28	Berlin Tegel Apt (DE)		29.514.664
29	Helsinki-Vantaa Apt (FI)		27.374.785
30	Athens Apt (EL)		25.393.842

Table B.2: European airlines flying to & from Europe retrieved from OAG (2018) based on scheduled flights and planned seat capacity; 23 airlines included in sample; 30 airlines included as keywords.

#	Carrier Name (Domicile Country)	In Sample	Total Seat Capacity
1	Ryanair (IE)	x	142.540.776
2	Easyjet (UK)	x	100.082.969
3	Turkish Airlines (TR)	x	91.560.208
4	Lufthansa German Airlines (DE)	x	89.606.683
5	British Airways (UK)	x	58.891.280
6	Air France (FR)		57.403.402
7	Aeroflot Russian Airlines (RU)	x	54.704.975
8	SAS Scandinavian Airlines (SE)	x	42.433.727
9	KLM-Royal Dutch Airlines (NL)	x	39.925.170
10	Vueling Airlines (ES)	x	39.519.020
11	Eurowings (DE)	x	36.731.238
12	Wizz Air (HU)	x	36.329.808
13	Pegasus Airlines (TR)	x	33.016.116
14	Iberia (ES)	x	31.277.293
15	Alitalia - Societa Aerea Italiana (IT)		30.728.937
16	Norwegian Air Shuttle (NO)	x	25.153.111
17	Swiss (CH)	x	24.146.541
18	TAP Air Portugal (PT)	x	20.504.640
19	Norwegian (IE)	x	18.686.220
20	Finnair (FI)	x	18.561.772
21	Austrian Airlines (AT)	x	18.348.903
22	Aer Lingus (IE)	x	16.501.640
23	Siberia Airlines (RU)		15.478.859
24	Air Europa (ES)	x	14.508.791
25	Flybe (UK)		14.095.905
26	Jet2.com (UK)	x	13.573.868
27	TUI Airways (UK)		12.923.015
28	LOT - Polish Airlines (PL)		12.863.577
29	Brussels Airlines (BE)	x	12.716.949
30	Condor Flugdienst (DE)		10.166.102

Table B.3: The 20 largest functional urban areas of the EU, by cities and commuting zones inhabitants, data from 2017 (Eurostat 19.3-2020), incl. primary public transport providers, bold names incl. in sample.

#	City	City (commuting zone) in m	Public transport provider(s) ^a
1	Paris (FR)	9,8 (12,8)	RATP (Autonomous Parisian Transportation Administration) ; SNCF (French National Railway Company)
2	London (UK)	8,8 (12,1)	TfL (Transport for London) ; Arriva Rail London; Hull Trains; Grand Central railway; Merseyrail; Chiltern Railways; Virgin Trains; Virgin Trains East Coast; ScotRail; London Overground; Heathrow Connect; Eurostar
3	Madrid (ES)	4,9 (6,6)	EMT (Madrid's Municipal Transport Corporation); RENFE (Renfe Operadora)
4	Berlin (DE)	3,6 (5,1)	BVG (Berlin Transport Company); VBB (Transport Association Berlin-Brandenburg); DB (Deutsche Bahn)
5	Milan (IT)	4,1 (5,1)	ATM (Azienda Trasporti Milanese); Trenitalia
6	Ruhr (DE) ^b	0,6 (5,1)	BVR (Busverkehr Rheinland) ; Vestische Straßenbahnen; Dortmunder Stadtwerke; Ruhrbahn; VRR (Transport Association Rhein-Ruhr); DB (Deutsche Bahn)
7	Barcelona (ES)	3,6 (4,9)	TMB (Transports Metropolitans de Barcelona) ; RENFE (Renfe Operadora)
8	Roma (IT)	2,9 (4,4)	ATAC (Transport Company of the Municipality of Rome); Trenitalia
9	Naples (IT)	3,1 (3,4)	ANM (Mobility Company of Naples); Trenitalia
10	Greater Manchester (UK)	2,8 (3,3)	TfGM (Transport for Greater Manchester) ; cf. London
11	Hamburg (DE)	1,8 (3,2)	HHA (Hamburger Hochbahn); HVV (Hamburg Transport Association); DB (Deutsche Bahn)
12	West Midlands urban area (UK)	2,5 (3,0)	TfWM (Transport for West Midlands) ; cf. London
13	Lisbon (PT)	1,8 (2,8)	Carris (Lisbon Tramways Company); Lisbon Metro ; CP (Trains of Portugal)
14	Budapest (HU)	1,8 (2,9)	BKK (Centre for Budapest Transport) ; MAV (Hungarian State Railways)
15	Munich (DE)	1,5 (2,8)	MVG (Munich Transportation Company) ; MVV (Munich Transport and Tarif Association); DB (Deutsche Bahn)
16	Stuttgart (DE)	0,6 (2,7)	SBB (Stuttgarter Straßenbahnen AG); VVS (Transport Association Stuttgart); DB (Deutsche Bahn)
17	Frankfurt a. M. (DE)	0,7 (2,6)	VGf (Stadtwerke Verkehrsgesellschaft Frankfurt a. M.); RMV (Rhein-Main-Transport Association); DB (Deutsche Bahn)
18	Brussels (BE)	1,2 (2,6)	STIB (Brussels Intercommunal Transport Company); NMBS / SNCB (National Railway Company of Belgium)
19	Leeds (UK)	0,8 (2,6)	WYPTE (West Yorkshire Passenger Transport Executive); cf. London
20	Amsterdam (NL)	0,8 (2,5)	GVB (Municipal Transport Company); NS (Nederlandse Spoorwegen)

^aCompany names are translated into English. *Verkehrsverbunde* do not provide operational transport services

^bOnly Ruhr cities over 500.000 inhabitants considered (Kreis Recklinghausen, Dortmund, Essen)

Table B.4: Companies search protocol from 20.3.2020 on Crunchbase (2020).

#	Search Steps
1	Founded: between 2015 and 2020
2	Headquartered: Europe
3	Industry (includes any): transportation, ride sharing, last mile transport, car sharing
4	Operating status: active
5	Exclude industries: delivery, food and beverage, customer service, health care, freight service, logistics, supply chain management, medical
6	Filter: estimated revenue range (descending)
7	Additional search for basic description contains "airport"
8	Top 33 analyzed for purpose of this study; 11 company used in this analysis

Table B.5: Basic dictionary, 225 entities.

Hypotheses	Metric (Keywords)
Personalization (H1)	<i>advertis*, customis*, flexibl*, individualis*, individualiz*, MaaS, need, on-demand, pattern, passeng*, personalis*, personaliz*, prefer*, recognit*, requir*, servic*, segment*, target*</i>
Passenger data (H2)	<i>analyt*, app, agent, autom*, blockchain*, biometr*, board*, catbot*, data*, data-min*, digitalis*, digitaliz*, digit*, element, experi*, home-print*, ident*, ML, Machin*, mine, mix*, predict*, realiti*, robot*, self-board*, self, SITA, tag, track*, virtual*</i>
Establishing partnerships (H3)	<i>add-on, Amazon, AI, Artifici*, Airbnb, air-rail*, booking.com, bundl*, C Teleport, Culture Trip, co-modal, collabor*, cooper*, Dohop, Dreamlines, door-to-door*, door*, D2D*, Evaneos, Flightsayer, GIVT, GetYourGuide, Google, HomeToGo, IATA, integr*, Intellig*, interfac*, intermod*, interoper*, Lumo, LuckyTrip, Maas Global, Mobian, multimodal*, Netflix, node*, Omio, partnership*, Resolver, start-up, Skyscanner, solut*, Selina, Secret Escapes, TravelPerk, Tiqets, wemovo, WeSki, (customized keywords depending on TSP: airline, airport, railway, bus, public transport providers)</i>
Environmentally friendly air transport (H4)	<i>altern*, awar*, ACA, biofuel*, carbon, CORSIA, compens*, diesel, decarbonis*, decarboniz*, drop-in, ecofriend*, energi*, environment*, environment-friend*, electrif*, emiss*, ETS, futur*, fuel, footprint, green, Gevo, Greenpeace, hydrogen*, kerosen, Neste, offset*, renew*, sustain*, shame*, SG Preston, Swedish Biofuels</i>
Airport feed (H5)	<i>access*, autonom*, BeeRides, Bipi, BlaBlaCar, Bolt, Blue Label, car, car&away, Cabify, concept, Cluno, driv*, egress, emerg*, FreeNow, feed*, FlixBus, hail*, innov*, last*, Lyft, mile, moovel, MyTaxi, novel, privat*, pool*, ride, RideLink, SeaBubbles, seamless*, share*, shuttl*, Sono Motors, Taxizairport, transrapid*, Uber, Viruo, Welcome Pickups</i>
Disruption management (H6)	<i>automat*, alert*, assist*, cascad*, custom*, care, congest*, delay*, disturb*, disrupt*, flow, itinerari*, network, notif*, push, rebook*, re-configur*, real, real-time, status, time</i>
Exogenous shocks (H7)	<i>attack*, crisi*, exogen*, epidem*, hygien*, health, luggage*, measur*, monitor*, pandem*, resili*, reaction*, recov*, regul*, secur*, screen*, safeti*, shock, terror*, terrorist*, WHO</i>

Table B.6: Top 40 mobility and transport-related companies; used as keywords.

#	Company Name	Short Description	H	Source
1	Sono Motors	Global mobility and energy service provider	H5	Crunchbase (2020)
2	Maas Global Oy	Mobility-as-a-Service operator	H3	Crunchbase (2020)
3	Bipi	Car subscription company	H5	Crunchbase (2020)
4	Viruo	Car Rental	H5	Crunchbase (2020)
5	Welcome Pickups	Airport pickup	H5	Crunchbase (2020)
6	Taxizairport.com	Online booking for airport transfers	H5	Crunchbase (2020)
7	Ridelink	P2P Car Rental platform (UK and Spain)	H5	Crunchbase (2020)
8	moovel Group	Urban mobility solutions	H5	Crunchbase (2020)
9	GIVT	Compensation services	H3	Crunchbase (2020)
10	BeeRides	Airport car sharing service	H5	Crunchbase (2020)
11	Blue Label	Private, low cost airport transfer	H5	Crunchbase (2020)
12	GetYourGuide	Offers tours and activities	H3	Luffhansa Innovation Hub (2020b)
13	FlixBus	Intercity mobility	H5	Luffhansa Innovation Hub (2020b)
14	Cabify	Ride hailing carpooling services	H5	Luffhansa Innovation Hub (2020b)
15	BlaBlaCar	Ride hailing carpooling services	H5	Luffhansa Innovation Hub (2020b)
16	Omio	Online search and booking	H3	Luffhansa Innovation Hub (2020b)
17	Bolt	Taxi services	H5	Luffhansa Innovation Hub (2020b)
18	Secret Escapes	Online travel agencies	H3	Luffhansa Innovation Hub (2020b)
19	Selina	Alternative housing	H3	Luffhansa Innovation Hub (2020b)
20	Cluno	Car rental & sharing	H5	Luffhansa Innovation Hub (2020b)
21	Dreamlines	Online search and booking	H3	Luffhansa Innovation Hub (2020b)
22	HomeToGo	Alternative housing	H3	Luffhansa Innovation Hub (2020b)
23	TravelPerk	Enterprise management software (business pax)	H3	Luffhansa Innovation Hub (2020b)
24	SeaBubbles	Intercity mobility	H5	Luffhansa Innovation Hub (2020b)
25	Tiqets	Offers tours and activities	H3	Luffhansa Innovation Hub (2020b)
26	Evaneos	Offers tours and activities	H3	Luffhansa Innovation Hub (2020b)
27	Culture Trip	Digital content & inspiration	H3	Luffhansa Innovation Hub (2020b)
28	C Teleport	Online travel agency	H3	Luffhansa Innovation Hub (2020a)
29	Mobian	Provides seamless, single ticketing	H3	Luffhansa Innovation Hub (2020a)
30	Resolver	Compensation services	H3	Luffhansa Innovation Hub (2020a)
31	LuckyTrip	Online travel agency	H3	Luffhansa Innovation Hub (2020a)
32	WeSki	Online travel agency	H3	Luffhansa Innovation Hub (2020a)
33	Dohop	Online travel agency	H3	Luffhansa Innovation Hub (2020a)
34	car&away	Parking and renting (UK)	H5	Luffhansa Innovation Hub (2020a)
35	Flightsayer (Lumo)	Flight delay predictions	H3	Luffhansa Innovation Hub (2020a)
36	Total ¹⁶	Major player renewable aviation fuels	H4	Mordor Intelligence (2020)
37	Neste	Major player renewable aviation fuels	H4	Mordor Intelligence (2020)
38	Swedish Biofuels	Major player renewable aviation fuels	H4	Mordor Intelligence (2020)
39	SG Preston	Major player renewable aviation fuels	H4	Mordor Intelligence (2020)
40	Gevo	Major player renewable aviation fuels	H4	Mordor Intelligence (2020)

¹⁶removed from analysis as word is too ambiguous

Table B.7: Data sample feeders: annual reports.

#	Company Name	Group owned by	Data Source	Retrieved on	Source Website
1	Arriva Rail London	DB	DB Integrated report 2018 (AR & SR)	16.04.2020	https://www.deutschebahn.com/en/gb_online-1213324
2	BKK (Centre for Budapest Transport)	BKV ^{tr}	Annual report 2018	16.04.2020	https://www.bkv.hu/ftp/annual_report/annualreport2018.pdf
3	BVR (Busverkehr Rheinland)	DB	DB Integrated report 2018 (AR & SR)	16.04.2020	https://www.deutschebahn.com/en/gb_online-1213324
4	Chiltern Railways	DB	DB Integrated report 2018 (AR & SR)	16.04.2020	https://www.deutschebahn.com/en/gb_online-1213324
5	DB (Deutsche Bahn Group)	DB	DB Integrated report 2018 (AR & SR)	16.04.2020	https://www.deutschebahn.com/en/gb_online-1213324
6	Eurostar	SNCF	SNCF Annual report 2019	15.04.2020	https://www.sncf.com/en/finance/financial-publications-sncf
7	Grand Central Railway	DB	DB Integrated report 2018 (AR & SR)	16.04.2020	https://www.deutschebahn.com/en/gb_online-1213324
8	Heathrow Connect	Heathrow Airport	Annual report and financial statements 2019	10.04.2020	https://www.heathrow.com/content/dam/heathrow/web/common/documents/company/investor-reports-and-presentations/annual-accounts/sp/Heathrow_SP_ARA_2019.pdf
9	Hull Trains	First	Annual report and accounts 2019	19.04.2020	https://www.firstgroupplc.com/investors/annual-report-2019.aspx
10	Lisbon Metro	TFL	Annual report and accounts 2018	16.04.2020	https://www.metrolisboa.pt/company/inform/documents/
11	London Overground	TFL	Annual report and statement of accounts 2018-19	16.04.2020	https://tfl.gov.uk/corporate/publications-and-reports/annual-report
12	MAV (Hungarian State Railways)		Consolidated annual financial statements 2018	17.04.2020	https://www.mavcsoport.hu/en/mav/introduction/publications
13	Merseyrail	NS	Annual report 2019	16.04.2020	https://www.nsannualreport.nl/annual-report-2019/introduction/2019-in-a-nutshell/
14	MYG (Munich Transportation Company)		AR not included in sample (read-only document)		
15	NMBS / SNCB (National Railway Company of Belgium)		Annual report 2018	17.04.2020	https://www.belgiantrain.be/en/about-sncb/enterprise/publications/en-annual-reports-2018
16	NS (Nederlandse Spoorwegen)	NS	NS annual report 2019	16.04.2020	https://www.nsannualreport.nl/annual-report-2019/introduction/2019-in-a-nutshell/
17	RATP (Autonomous Parisian Transportation Administration)		Activity and sustainability development report 2018	16.04.2020	https://www.ratp.fr/en/groupe-ratp/group-presentation/our-essential-documents
18	ScotRail	NS	NS annual report 2019	16.04.2020	https://www.nsannualreport.nl/annual-report-2019/introduction/2019-in-a-nutshell/
19	SNCF (French National Railway Company)		Annual report 2019	15.04.2020	https://www.sncf.com/en/finance/financial-publications-sncf
20	TfGM (Transport for Greater Manchester)		Statement of accounts for the year ended 31 March 2019	17.04.2020	https://tfgm.com/corporate/statement-of-accounts
21	TfL (Transport for London)	TfL	Annual report and statement of accounts 2018-19	16.04.2020	https://tfl.gov.uk/corporate/publications-and-reports/annual-report
22	TfWM (Transport for West Midlands)		Annual plan report 2019-20	17.04.2020	https://www.wmca.org.uk/what-we-do/transport/
23	TMB (Transportis Metropolitans de Barcelona)		Company presentation 2019	17.04.2020	https://www.tmb.cat/en/about-tmb/get-to-know-us/publications-and-corporate-documents?q=corporatu
24	Trenitalia		Service quality report 2018	16.04.2020	https://www.trenitalia.com/content/dam/tcom/en/info-and-contacts/Quality_Report_2018.pdf
25	Virgin Trains	Stagecoach Group	Stagecoach group annual report 2019	20.04.2020	https://www.stagecoachgroup.com/media/resources-library/publications/financial-reports
26	Virgin Trains East Coast	Stagecoach Group	Stagecoach group annual report 2019	20.04.2020	https://www.stagecoachgroup.com/media/resources-library/publications/financial-reports

^{tr}Budapest Transport Privately Held Corporation owned by the Municipality of Budapest

Table B.8: Data sample feeders: sustainability reports.

#	Company Name	Additional document (sustainability report or other related material)	Retrieved on	Source Website
1	Arriva Rail London	incl. in integrated report		
2	BKK (Centre for Transport)	not available		
3	BVR (Busverkehr Rheinland)	incl. in integrated report		
4	Chiltern Railways	incl. in integrated report		
5	DB (Deutsche Bahn Group)	incl. in integrated report		
6	Eurostar	Corporate social engagement report 2018	15.04.2020	https://www.sncf.com/en/finance/financial-publications-sncf
7	Grand Central Railway	incl. in integrated report		
8	Heathrow Connect	incl. in LHR report		
9	Hull Trains	Environmental data report 2019	20.04.2020	https://www.firstgroupplc.com/responsibility/responsibility-reports/2019.aspx
10	Lisbon Metro	last version from 2007 (not included)		
11	London Overground	Health, safety and environment annual report 2018/19	20.04.2020	https://tfl.gov.uk/corporate/publications-and-reports/health-safety-and-environment
12	MAV (Hungarian State Railways)	not available		
13	Merseyrail	incl. in AR		
14	MVG (Munich Transportation Company)	Sustainability report 2014/2015	16.04.2020	https://www.mvg.de/ueber/engagement/nachhaltigkeit.html
15	NIMBS / SNCB (National Railway Company of Belgium)			
16	NS (Nederlandse Spoorwegen)	incl. in AR		
17	RATP (Autonomous Parisian Transportation Administration)	SR not included in sample (read-only document)		
18	ScotRail	incl. in AR		
19	SNCF (French National Railway Company)	Corporate social engagement report 2018	15.04.2020	https://www.sncf.com/en/finance/financial-publications-sncf
20	TfGM (Transport for Greater Manchester)	Business Plan for making travel easier in Greater Manchester 2018 - 21	17.04.2020	https://tfgm.com/corporate/statement-of-accounts
21	TfL (Transport for London)	Health, safety and environment annual report 2018/19	20.04.2020	https://tfl.gov.uk/corporate/publications-and-reports/health-safety-and-environment
22	TfWM (Transport for West Midlands)	Combined Authority Sustainability Benchmarking, Technical Report – annual analysis of metrics	20.04.2020	http://www.sustainabilitywestmidlands.org.uk/wp-content/uploads/WMCA-Sustainability-Metrics-Report-Final-May-2018.pdf
23	TMB (Transports Metropolitanos de Barcelona)	SR only in Spanish		
24	Trenitalia	FS Italiane group sustainability report 2018	16.04.2020	https://www.fsitaliane.it/content/fsitaliane/en/sustainability/sustainability-report.html
25	Virgin Trains		20.04.2020	https://www.stagecoachgroup.com/sustainability/our-strategy.aspx
26	Virgin Trains East Coast		20.04.2020	https://www.stagecoachgroup.com/sustainability/our-strategy.aspx

Table B.9: Data sample airlines: annual reports.

#	Company Name	Group / Data Source owned by	Retrieved on	Source Website
27	Air Europa	IAG	10.04.2020	https://www.iairgroup.com/en/newsroom/financial-results
28	Aeroflot Russian Airlines		10.04.2020	https://ir.aeroflot.com/shareholders-and-investors/
29	Lufthansa German Airlines (DLH)	DLH	07.04.2020	https://www.lufthansagroup.com/en/themes/annual-report-2019.html
30	Eurowings	DLH	07.04.2020	https://www.lufthansagroup.com/en/themes/annual-report-2019.html
31	Swiss	DLH	07.04.2020	https://www.lufthansagroup.com/en/themes/annual-report-2019.html
32	Austrian Airlines	DLH	07.04.2020	https://www.lufthansagroup.com/en/themes/annual-report-2019.html
33	Aer Lingus	IAG	10.04.2020	https://www.iairgroup.com/en/newsroom/financial-results
34	Jet2.com		12.04.2020	https://www.jet2.com/News/Dart_Group_Publishes_Annual_Report_2019/
35	Easyjet		07.04.2020	http://corporate.easyjet.com/investors/reports-and-presentations/2019
36	Finnair	IAG	11.04.2020	https://investors.finnair.com/en/reports-and-presentations
37	Iberia	IAG	10.04.2020	https://www.iairgroup.com/en/newsroom/financial-results
38	Royal Dutch (KLM)	Airlines	10.04.2020	https://annualreports.klm.com/
39	Norwegian Air Shuttle	Norwegian	11.04.2020	https://www.norwegian.com/de/tuber-uns/company/investor-relations/reports-and-presentations/
40	Norwegian	Norwegian	11.04.2020	https://www.norwegian.com/de/tuber-uns/company/investor-relations/reports-and-presentations/
41	Pegasus Airlines		10.04.2020	http://www.pegasusinvestorrelations.com/en/operational-information/annual-reports
42	Ryanair		10.04.2020	https://investor.ryanair.com/wp-content/uploads/2019/07/Ryanair-2019-Annual-Report.pdf
43	Scandinavian (SAS)	Airlines	10.04.2020	https://www.sasgroup.net/investor-relations/financial-reports/annual-reports/sas-annual-and-sustainability-report-fiscal-year-2019/
44	TAP Air Portugal		11.04.2020	https://www.tapairportugal.com/en/about-us/annual-reports
45	Turkish Airlines		10.04.2020	https://investor.turkishairlines.com/en/financial-and-operational/annual-reports
46	Vueling Airlines	IAG	10.04.2020	https://www.iairgroup.com/en/newsroom/financial-results
47	Wizz Air		10.04.2020	https://wizzair.com/en-gb/information-and-services/investor-relations/investors/annual-reports
48	Brussels airlines	DLH	07.04.2020	https://www.lufthansagroup.com/en/themes/annual-report-2019.html
49	British Airways	IAG	10.04.2020	https://ir.aeroflot.com/shareholders-and-investors/

Table B.10: Data sample airlines: sustainability reports.

#	Company Name	Additional document (sustainability report or other related material)	Retrieved on	Source Website
27	Air Europa	Non-financial information 2019	11.04.2020	https://www.iairgroup.com/en/sustainability/documents-and-links
28	Aeroflot Russian Airlines	incl. in AR		
29	Lufthansa German Airlines (DLH)	Sustainability report 2019	11.04.2020	https://www.lufthansagroup.com/en/responsibility/sustainability-reports.html
30	Eurowings	Sustainability report 2019	11.04.2020	https://www.lufthansagroup.com/en/responsibility/sustainability-reports.html
31	Swiss	Sustainability report 2019	11.04.2020	https://www.lufthansagroup.com/en/responsibility/sustainability-reports.html
32	Austrian Airlines	Sustainability report 2019	11.04.2020	https://www.lufthansagroup.com/en/responsibility/sustainability-reports.html
33	Aer Lingus	Non-financial information 2019	11.04.2020	https://www.iairgroup.com/en/sustainability/documents-and-links
34	Jet2.com	not available		
35	Easyjet	incl. in AR		
36	Finnair	Sustainability report 2019	11.04.2020	https://investors.finnair.com/en/reports-and-presentations
37	Iberia	Sustainability report 2018	11.04.2020	https://grupo.iberia.com/sustainability/reports
38	Royal Dutch Airlines (KLM)	AirFranceKLM Group report 2018 (AirFrance annual report n/a and excluded from sample)	11.04.2020	https://csreport2018.airfranceklm.com/en/
39	Norwegian Air Shuttle	Sustainability report 2018	11.04.2020	https://www.norwegian.com/de/uber-uns/company/investor-relations/reports-and-presentations/
40	Norwegian	Sustainability report 2018	11.04.2020	https://www.norwegian.com/de/uber-uns/company/investor-relations/reports-and-presentations/
41	Pegasus Airlines	Sustainability report 2018	11.04.2020	http://www.pegasusinvestorrelations.com/en/corporate-governance/sustainability
42	Ryanair	Environmental Policy (Vol. 2 - 2020)	11.04.2020	https://corporate.ryanair.com/environment/
43	Scandinavian Airlines (SAS)	incl. in AR		
44	TAP Air Portugal	Ethics code and Company's Good Business Conduct 2018	11.04.2020	https://www.tapairportugal.com/en/about-us/manuals
45	Turkish Airlines	Sustainability report 2018	11.04.2020	https://investor.turkishairlines.com/en/corporate-governance/sustainability
46	Vueling Airlines	Non-financial information 2019	11.04.2020	https://www.iairgroup.com/en/sustainability/documents-and-links
47	Wizz Air	not available		
48	Brussels airlines	Sustainability report 2019	11.04.2020	https://www.lufthansagroup.com/en/responsibility/sustainability-reports.html
49	British Airways	Non-financial information 2019	11.04.2020	https://www.iairgroup.com/en/sustainability/documents-and-links

Table B.11: Data sample airports: annual reports.

#	Company Name	Group / owned by	Data Source	Retrieved on	Source Website
50	Amsterdam Apt		Annual report 2019	10.04.2020	https://www.annualreportschiphol.com/xmlpages/resources/TXP/Schiphol_web_2019/pdf/Schiphol_Annual_Report_2019.pdf
51	Barcelona Apt	Aena	Aena management report 2019	13.04.2020	http://www.aena.es/csee/Satellite/Accionistas/en/Page/1237572838468/1237568522644/
52	Brussels Apt		Company report 2018	14.04.2020	https://www.brusselairport.be/en/our-airport/facts-figures/bruttrends
53	Copenhagen Kastrup Apt		Group annual report 2019	10.04.2020	https://www.cph.dk/en/about-cph/investor/publications
54	Dublin Apt		Annual report 2018	10.04.2020	https://www.daa.ie/media-centre/annual-reports/
55	Duesseldorf Intl. Apt	TAV Airports	Annual report 2018	10.04.2020	https://www.dus.com/en/services/downloadcenter
56	Istanbul Ataturk Apt	TAV Airports	TAV Annual report 2019	10.04.2020	http://www.tavyatirimciliskileri.com/en-EN/Pages/Annual.aspx
57	Lisbon Apt	ANA Aeropor- tos de Portugal	ANA annual report 2018	10.04.2020	https://www.ana.pt/en/corporate/reports/annual-reports
58	London Gatwick Apt		Annual report 2019	10.04.2020	https://www.gatwickairport.com/business-community/about-gatwick/investor-relations/reports/
59	London Heathrow Apt		Annual report and financial statements 2019	10.04.2020	https://www.heathrow.com/content/dam/heathrow/web/common/documents/company/investor/reports-and-presentations/annual-accounts/sp/Heathrow_SP_ARA_2019.pdf
60	London Stansted Apt	MAG	MAG annual report 2019	10.04.2020	https://www.magairports.com/investor-relations/annual-and-interim-reports/
61	Madrid Adolfo Suarez- Barajas Apt	Aena	Aena management report 2019	13.04.2020	http://www.aena.es/csee/Satellite/Accionistas/en/Page/1237572838468/1237568522644/
62	Manchester (GB) Apt	MAG	MAG annual report 2019	10.04.2020	https://www.magairports.com/investor-relations/annual-and-interim-reports/
63	Moscow Sheremetyevo Intl. Apt		Annual report 2018	13.01.1900	https://www.svo.aero/en/about/investors
64	Oslo Gardermoen Apt	Avinor (AG)	AG Annual and sustainability report 2019	10.04.2020	https://avinor.no/en/corporate/about-us/reports/reports
65	Palma de Mallorca Apt	Aena	Aena consolidated management report for the year ended 31 December 2019	13.04.2020	http://www.aena.es/csee/Satellite/Accionistas/en/Page/1237572838468/1237568522644/
66	Paris Charles de Gaulle Apt	Adp (Aéroports de Paris) Group	Adp management report 2018	10.04.2020	https://www.parisaeroport.fr/docs/default-source/groupe-fichiers/finance/actionnaires-individuels/assemblee-generale/2019/en-rapport-de-gestion.pdf?sfvrsn=e77cfbbd_6
67	Paris Orly Apt	Adp Group	Adp management report 2018	10.04.2020	https://www.parisaeroport.fr/docs/default-source/groupe-fichiers/finance/actionnaires-individuels/assemblee-generale/2019/en-rapport-de-gestion.pdf?sfvrsn=e77cfbbd_6
68	Rome Fiumicino Apt	Aeroporti Roma (ADR)	ADR Annual report 2018	10.04.2020	https://www.adr.it/documents/17615/14928122/ADR_RFA+2018_eng.pdf/c7ab4451-c1d3-44a4-a6a0-5556c8f5b60a
69	Stockholm Arlanda Apt	Swedavia Airport Group report (SAG)	Air- SAG Annual and sustainability report 2018	14.04.2020	https://www.swedavia.com/about-swedavia/financial-information/
70	Vienna Intl. Apt		Annual report 2018	10.04.2020	https://www.viennaairport.com/en/company/investor_relations/publications_and_reports/annual_reports
71	Zurich Apt		Annual report 2019	14.04.2020	https://report.flughafen-zuerich.ch/2019/ar/en/download-center-2/

Table B.12: Data sample airports: sustainability reports.

#	Company Name	Additional document (sustainability report or other related material)	Retrieved on	Source Website
50	Amsterdam Apt	not available		
51	Barcelona Aapt	Non-financial information corporate responsibility report 2018	10.04.2020	http://www.aena.es/csee/ccurl/281/638/Informe-RC3-2018-EN.pdf
52	Brussels Apt	Environmental report 2019	14.04.2020	https://www.brusselsairport.be/en/environment/environment-report-2019
53	Copenhagen Kastrup Apt	not available		
54	Dublin Apt	Sustainability update 2016/2017	14.04.2020	https://www.daa.ie/our-company/sustainability/sustainability-reports/
55	Duesseldorf Intl. Apt	n/a in English		
56	Istanbul Ataturk Apt	TAV sustainability report 2014/15	13.04.2020	http://www.tavyatirimciliskileri.com/en-EN/
57	Lisbon Apt	Environmental performance report 2018	14.04.2020	https://www.ana.pt/en/corporate/reports/environmental-performance-reports
58	London Gatwick Apt	Performance report 2018	14.04.2020	https://www.gatwickairport.com/business-community/community-sustainability/sustainability/sustainability-reports/
59	London Heathrow Apt	Sustainability Progress 2018	12.04.2020	https://www.heathrow.com/company/about-heathrow/heathrow-2-0-sustainability-strategy
60	London Stansted Apt	MAG Corporate social responsibility report 2018/19	14.04.2020	https://www.magairports.com/responsible-business/csr-reports/
61	Madrid Adolfo Suarez-Barajas Airport	Non-financial information corporate responsibility report 2018	10.04.2020	http://www.aena.es/csee/ccurl/281/638/Informe-RC3-2018-EN.pdf
62	Manchester (GB) Apt	MAG Corporate social responsibility report 2018/19	14.04.2020	https://www.magairports.com/responsible-business/csr-reports/
63	Moscow Intl. Apt	Sheremetyevo not available		
64	Oslo Gardermoen Apt	incl. in AR		
65	Palma de Mallorca Apt	Non-financial information corporate responsibility report 2018	10.04.2020	http://www.aena.es/csee/ccurl/281/638/Informe-RC3-2018-EN.pdf
66	Paris Charles de Gaulle Apt	ADP Information on corporate social responsibility 2018	12.04.2020	https://www.parisaeroport.fr/en/group/csr/balance-sheet-and-index/documents
67	Paris Orly Apt	ADP Information on corporate social responsibility 2018	12.04.2020	https://www.parisaeroport.fr/en/group/csr/balance-sheet-and-index/documents
68	Rome Fiumicino Apt	not available		
69	Stockholm Arlanda Apt	incl. in AR		
70	Vienna Intl. Apt	incl. in AR		
71	Zurich Apt	incl. in AR		

Table B.13: Overview training dataset.

Segment	Company name	Data source used in Retrieved model	Date	Source website
Airlines' textual data	Emirates annual report 2018-19	parts of report	11.04.2020	https://www.emirates.com/de/english/about-us/financial-transparency/annual-reports/
Airlines' textual data	Qatar Airways Sustainability report 2018	parts of report	11.04.2020	https://www.qatarairways.com/en-be/about-qatar-airways/environmental-awareness.html
Airlines' textual data	Qatar Airways Annual report 2019	parts of report	15.08.2020	https://www.qatarairways.com/de-de/about-qatar-airways/annual-reports.html
Airports' textual data	Los Angeles World Airport annual report 2018-19	parts of report	15.08.2020	https://www.lawa.org/lawa-investor-relations
Airports' textual data	Geneva Airport annual report 2019	parts of report	15.08.2020	https://www.gva.ch/en/Site/Geneve-Aeroport/Publications/Institutionnel
Feeders' textual data	Swedish Transport Administration sustainability and annual report 2018	parts of report	15.08.2020	https://trafikverket.meko.se/se/%C3%A5str%C3%A5redovisning-2
Feeders' textual data	ÖBB-Holding AG Annual report 2019	parts of report	15.08.2020	https://presse.oebb.at/en/publications
Scientific paper	Kluge et al. (2020)	Parts of paper	15.08.2020	https://www.sciencedirect.com/science/article/pii/S0040162520309227
Report	Skift 2019 Megatrends Report	parts of report	16.08.2020	https://skift.com/megatrends-2019/
Report	Sita: Air travel for a digital age	parts of report	16.08.2020	https://www.sita.aero/resources/type/white-papers/air-travel-for-a-digital-age
Feeders' textual data	Draft LEP Annual Delivery Plan Content	parts of report	22.10.2020	https://www.the-lep.com/about-us/annual-review-201920-and-delivery-plan-202021/
Feeders' textual data	Renfe Sustainable report	parts of report	17.04.2020	https://www.renfe.com/EN/empresa/RSE/InformesRSEyGobiernoCorporativo.html
Scientific paper	Linden (2020)	paper, checklist at end of conclusion	24.10.2020	https://doi.org/10.1016/j.jairtraman.2020.101944
Scientific paper	Baumgartner et al. (2017) DORA	parts of paper	24.10.2020	https://www.sciencedirect.com/science/article/pii/S2352146516302745
Report	Future Travel Experience - PaxEx & Ancillary Think Tank - presentation	parts of report	08.02.2020	https://www.futuretravalexperience.com/think-tanks/ancillary-paxex-think-tank/
Scientific paper	Accenture: Blockchain technology for airlines	parts of report	25.10.2020	https://www.accenture.com/hu-en/insights/travel/blockchain-technology-airlines
Scientific paper	Li et al. (2018)	parts of Introduction and conclusion	23.06.2020	https://doi.org/10.1016/j.jairtraman.2018.06.002
Report	Lufthansa Innovation Hub: The state of travel & mobility tech report (2019)	parts of report		
Report	svb Silicon Valley Bank Future of mobility	parts of report		
Scientific paper	Cassetta et al. (2017)	parts of paper ^a	25.10.2020	https://doi.org/10.1016/j.j-tra.2017.09.009
Scientific paper	Wadud (2020)	parts from introduction, literature review	25.10.2020	https://doi.org/10.1016/j.jairtraman.2020.101783
Scientific paper	lang & Mohnen (2019)	abstract, parts of introduction and Section 2	25.10.2020	https://doi.org/10.1016/j.eist.2019.01.005
Report	McKinsey Report: The future of mobility is on our doorstep	parts of mobility is most parts of it	25.10.2020	https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/The%20future%20of%20mobility%20is%20at%20our%20doorstep/The-future-of-mobility-is-at-our-doorstep.pdf
Scientific paper	Postoriona et al. (2020)	parts from Introduction & conclusion	25.10.2020	https://doi.org/10.1016/j.cstp.2020.03.007
Scientific paper	Bagamanova & Mota (2020)	parts of Introduction	25.10.2020	https://doi.org/10.1016/j.jairtraman.2019.101757
Scientific paper	Wenzel et al. (2020)	almost entire paper	26.10.2020	https://onlinelibrary.wiley.com/doi/abs/10.1002/smj.3161
Scientific paper	Albers & Rundshagen (2020)	almost entire paper	13.08.2020	https://doi.org/10.1016/j.jairtraman.2020.101863
Scientific paper	Kao et al. (2020)	almost entire paper	27.10.2020	https://doi.org/10.1016/j.jairtraman.2020.101894

^atitle, highlights, abstract and keywords, parts of introduction, results, conclusion



Appendix 3

C.1 TABLES

Table C.1: Fare (€) for one way (outbound) from Frankfurt Airport (FRA) to New York City (JFK and EWR) in premium-economy (RDC 2021).

Travel Period	Airline	Cabin	Sector Length (km)	6 Month	3 Month	1 Month	1 Week	Weighted Average Fare
2020	LH	Premium	6539	355.65	264.37	389.34	540.1	450.13
2019	LH	Premium	6522	-	511.49	622.57	769.24	598.27

The displayed fares include taxes and fees but no additional costs, such as credit card fees or seat selection fees. To include some of these additional costs, the fare for this study is rounded to €550. Two free pieces of luggage each max. 23 kg are assumed to be included, as taken from the Lufthansa booking page (Lufthansa 2021).

Table C.2: Fit statistics of HB models for testing model convergence (Sawtooth Software 2021b).

Sample	Iterations (sampling iterations for respondent)	Percent certainty iter- each (Pct. Cert.)	Root-likelihood (RLH)	Average Variance	Parameter RMS	Computing Time
N = 269	10,000	0.749	0.668	3.587	3.095	01:03
N = 396	10,000	0.736	0.654	3.179	2.915	01:21
N = 269	20,000	0.746	0.664	3.491	3.093	02:13
N = 269	30,000	0.748	0.666	3.365	3.045	03:10
N = 269	40,000	0.752	0.671	3.703	3.186	04:15
N = 269	50,000	0.751	0.67	3.598	3.126	05:43

Average values calculated: $\text{average values} = .01 * (\text{new value}) + .99 * (\text{old average})$

Table C.3: Count analysis of the attributes.

Attribute	Level	Total Proportion	Statistics	
Total price flight¹ upgrades	€100	0.346	Within Att. Chi-Square	1353.21
	€200	0.146	D.F.	3
	€300	0.065	Significance	p <.01
	€400	0.026		
CO₂-contribution	not included	0.083	Within Att. Chi-Square	349.29
	included	0.209	D.F.	1
			Significance	p <.01
In-flight meal upgrade	not included	0.126	Within Att. Chi-Square	33.99
	included	0.165	D.F.	1
			Significance	p <.01
On-board hygiene upgrade	no upgrade	0.128	Within Att. Chi-Square	15.2
	amenity kit	0.149	D.F.	2
	sanitized seat	0.16	Significance	p <.01
Seat upgrade (comfort)	no upgrade	0.058	Within Att. Chi-Square	468.32
	empty seat next to you	0.14	D.F.	3
	emergency exit seat	0.125	Significance	p <.01
	business class seat	0.26		
Multimodal ticket- ing: surface transport	not included	0.116	Within Att. Chi-Square	77.9
	included	0.175	D.F.	1
			Significance	p <.01
No purchase	non alternative	0.417		

¹Counts add up to 100% as all prices and non option were shown in all choice sets.

Table C.4: Relative level part-worth utilities - overall sample.

Attribute	Level	Frequentist, N=269 raw scaled (output Lighthouse Studio)		Bayesian (Orme & Chrzan, 2017) ^a		
		Utility (draws respondents)	SD ^b (draws respondents)	95% CI ^c (draws respondents)	95% CI (alpha draws)	SD (alpha draws)
Total price flight upgrades	€100	4.89	2.33	[4.61; 5.17]	[4.23; 5.61]	0.34
	€200	1.9	0.91	[1.79; 2]	[1.37; 2.43]	0.27
	€300	-1.65	1.06	[-1.78; -1.52]	[-2.46; -1.17]	0.34
	€400	-5.14	2.07	[-5.39; -4.89]	[-6.27; -3.86]	0.67
CO ₂ -compensation	not included	-1.47	1.14	[-1.6; -1.33]	[-1.73; -1.24]	0.13
	included	1.47	1.14	[1.33; 1.6]	[1.24; 1.73]	0.13
In-flight meal upgrade	no upgrade	-0.45	0.67	[-0.53; -0.37]	[-0.63; -0.27]	0.09
	gourmet meal	0.45	0.67	[0.37; 0.53]	[0.27; 0.63]	0.09
On-board hygiene upgrade	no upgrade	-0.32	0.54	[-0.38; -0.25]	[-0.51; -0.12]	0.10
	amenity kit	0.02	0.41	[-0.03; 0.07]	[-0.17; 0.21]	0.10
	sanitized seat	0.3	0.38	[0.25; 0.34]	[0.07; 0.49]	0.11
	no upgrade	-2.44	1.21	[-2.58; -2.29]	[-2.89; -2.02]	0.22
Seat upgrade comfort	empty seat next to you	0.28	0.83	[0.18; 0.38]	[0; 0.57]	0.15
	emergency exit seat	0.01	0.53	[-0.05; 0.07]	[-0.25; 0.26]	0.13
	business class seat	2.15	1.87	[1.92; 2.37]	[1.78; 2.52]	0.19
Multimodal ticketing	not included	-0.79	0.68	[-0.87; -0.71]	[-0.98; -0.61]	0.09
	included	0.79	0.68	[0.71; 0.87]	[0.61; 0.98]	0.09
No purchase (non alternative)		5.73	3.79	[5.28; 6.18]	[4.98; 6.57]	0.40

^aCalculated in R^bSD: standard deviation^c[lower 95% confidence interval (CI); upper 95% confidence interval]

Table C.5: Partial utilities - by gender, travel purpose and membership of frequent flyer programs.

Attribute	Level	Male	Female	Bayesian degree of certainty	Leisure pax	Business pax	Bayesian degree of certainty	FF member	FF ^a non-member	Bayesian degree of certainty
Total price flight upgrades	€100	5.12	4.98	61%	3.66	3.79	57%	4.66	5.36	93%
	€200	2.09	1.98	63%	1.29	1.54	68%	1.98	1.93	57%
	€300	-1.76	-1.58	69%	-1.43	-0.62	91%	-1.77	-2.02	78%
	€400	-5.44	-5.38	53%	-3.52	-4.71	90%	-4.87	-5.27	72%
CO2-compensation	not included	-1.04	-2.02	100%	-1.51	-0.6	98%	-1.22	-1.78	100%
	included	1.04	2.02	100%	1.51	0.6	98%	1.22	1.78	100%
In-flight meal upgrade	no upgrade	-0.52	-0.41	75%	-0.2	-0.32	64%	-0.59	-0.36	92%
	gourmet meal	0.52	0.41	75%	0.2	0.32	64%	0.59	0.36	92%
On-board hygiene upgrade	no upgrade	-0.18	-0.45	91%	-0.39	0.17	93%	-0.31	-0.32	51%
	amenity kit	0.07	0.01	63%	-0.01	-0.58	95%	0.04	0.04	0%
	sanitized seat	0.12	0.44	96%	0.4	0.4	1%	0.27	0.28	53%
Seat upgrade (comfort)	no upgrade	-2.82	-2.18	98%	-2.02	-2.61	81%	-3.06	-1.99	100%
	empty seat next to you	0.19	0.42	84%	0.14	-0.25	80%	0.15	0.42	85%
	emergency exit seat	-0.06	0.09	74%	-0.07	-0.25	65%	-0.08	0.12	79%
	business class seat	2.68	1.67	100%	1.94	3.12	96%	2.98	1.45	100%
Multimodal ticketing	not included	-0.7	-0.93	91%	-0.49	-0.15	85%	-0.7	-0.94	91%
	included	0.7	0.93	91%	0.49	0.15	85%	0.7	0.94	91%

^afrequent flyer

C.2 FIGURES

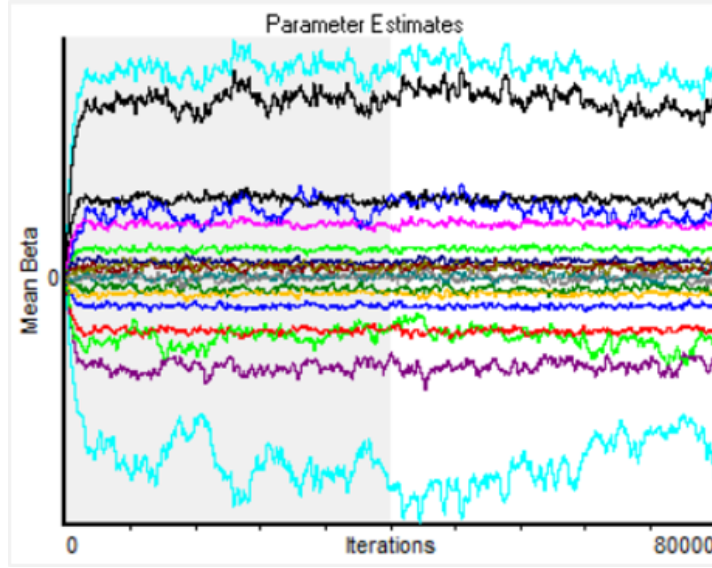


Figure C.1: Plot of the parameter estimation for 80,000 iterations, of which 40,000 burn-in iterations are not used (gray area).

C.3 ADDITIONAL INFORMATION

Econometric model

The unobservable error term ε is assumed to be independent, identical and equally distributed using the Gumbel distribution with a variance of $\pi^2/6$ (McFadden 1974). The individual density and cumulative distribution are as follows Train (2009):

$$f(\varepsilon_{nj}) = e^{-\varepsilon_{nj}} e^{-e^{-\varepsilon_{nj}}} \quad (\text{C.1})$$

$$F(\varepsilon_{nj}) = e^{-e^{-\varepsilon_{nj}}} \quad (\text{C.2})$$

The distance $\varepsilon_{nji}^* = \varepsilon_{nj} - \varepsilon_{ni}$ between the extreme values is distributed logistically leading to:

$$F(\varepsilon_{nji}^*) = \frac{e^{\varepsilon_{nji}^*}}{1 + e^{\varepsilon_{nji}^*}} \quad (\text{C.3})$$

Taken the RUT framework $U_{nj} = V_{nj} + \varepsilon_{nj}(\forall j)$, it is assumed that i is chosen over j if:

$$U_{ni} > U_{nj}, \forall j \neq i \quad (\text{C.4})$$

and

$$(V_{ni} - V_{nj}) > (\varepsilon_{nj} - \varepsilon_{ni}). \quad (\text{C.5})$$

Following McFadden (1974), the logit choice probability can be derived since the error term is distributed. Derived from the RUT, the model is in line with the behavior of utility maximization.

$$\begin{aligned} P_{ni} &= \text{Prob}(U_{ni} > U_{nj}, \forall j \neq i) \\ P_{ni} &= \text{Prob}(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}, \forall j \neq i) \\ P_{ni} &= \text{Prob}(\varepsilon_{nj} < \varepsilon_{ni} + V_{ni} - V_{nj}, \forall j \neq i) \end{aligned} \quad (\text{C.6})$$

Given the cumulative distribution and ε_{nj} being independent, the product of the cumulative distribution is as follows:

$$P_{ni} | \varepsilon_{ni} = \prod_{j \neq i} e^{-e^{(\varepsilon_{ni} + V_{ni} - V_{nj})}} \quad (\text{C.7})$$

The choice probability can be rewritten as an integral weighted by the density given in Equation C.1.

$$\begin{aligned} P_{ni} &= \int \left(\prod_{j \neq i} e^{-e^{(\varepsilon_{ni} + V_{ni} - V_{nj})}} \right) e^{-\varepsilon_{ni}} e^{-e^{-\varepsilon_{ni}}} d\varepsilon_{ni} \\ &= \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} \end{aligned} \quad (\text{C.8})$$

Given $V_{nj} = \beta' X_{nj}$, the logit model can be derived:

$$P_{ni} = \frac{e^{\beta' X_{ni}}}{\sum_j e^{\beta' X_{nj}}} \quad (\text{C.9})$$

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