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ANALYSIS OF PASSENGER PREFERENCES ON REGIONAL AIR TRANSPORT IN GERMANY BASED ON STATED PREFERENCE DATA

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Abstract

Based on electrified regional commuter aircraft concepts, short-haul services provide many opportunities, such as higher time efficiency within the overall network and reduced travel emissions in reaching regional airports. This study aimed to understand how the relevant service attributes and individual characteristics affect preferences of 19-passenger commuter aircraft. Two mode choice models were estimated based on empirical survey data collected from representative private and business travelers. The reported high mode share and calculated high willingness-to-pay for saving door-to-door travel times as well as reducing total CO_2-eq emissions indicated the prospect of introducing regional air transport service served by 19-passenger hybrid-electric aircraft to the business travel market, especially for longer-distance travel (above 500 km). This implies that not only travel efficiency and sustainability need to be ensured from the standpoint of aircraft design but also the necessity of new business models to promote the efficiency of intermodal travel, including first and last miles and transfer procedures. Policy implications regarding other stakeholders are provided for improving the adoption of hybrid-electric aircraft and other low-emission transport modes.

Keywords

regional air transport; hybrid-electric commuter aircraft; passenger preference; transport mode choice

NOMENCLATURE

CO_2-eq	CO_2-equivalent
CSR	Corporate Social Responsibility
HEA	hybrid-electric aircraft
IPCC	Intergovernmental Panel on Climate Change
MaxDiff	Maximum Difference Scaling
MiD	German household travel survey (Mobilitaet in Deutschland)
MNL	multinomial logit model
MRS	marginal rate of substitution
NUTS	Nomenclature of territorial units for statistics
RPK	revenue passenger kilometer
RP	revealed preference
SME	small to medium-sized enterprise
SP	stated preference
WTP	willingness to pay

1. INTRODUCTION

Introducing aircraft powered by renewable energy, such as electricity or hydrogen, is seen as one option to reach climate neutrality in aviation. In this study, we focus on regional and short-haul applications, which bring new possibilities to connect small regional airports and reduce access and egress times to/from the airports. Therefore, there can be a higher time efficiency in terms of door-to-door travel, including first and last miles. This study, contributing to the project GNOSIS [1], focuses on 19-seater, propeller-driven hybrid-electric aircraft (HEA) with conventional take-off and landing features, which incorporate fuel cells and batteries, visioning a market entry in 2050 [2]. The project evaluates HEA configurations that can be equipped with seats for up to 19 passengers and achieve an operating range of up to 950 km [1, 3], which is comparable to the selected reference aicraft - Beechcraft 1900D. Here, we name it as conventional 19-seater. HEA can use existing airfields and airports and is expected to fill a place in the market that is currently taken by less environmentally friendly aircraft [2]. The reference design mission for the aircraft analyses includes the trip from origin to destination airport at 23,000 ft cruise altitude and Mach 0.4 cruise speed, a 100 NM alternate distance, 45 minutes holding reserves, as well as 10 minutes taxi time at origin and destination airports [4].

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Recently, an increasing amount of studies have focused on aircraft comprising new technologies. With a focus on 19-seater HEAs, most research has concentrated on technological development and aircraft design, while evaluating the potential market and demand has received little attention. The state-of-the-art research on market and demand analysis is summarized in Section 2. These studies investigated the potential market, estimated the market share, or analyzed the potential benefits of electric or hybrid-electric aircraft based on secondary data, such as existing travel surveys or travel times and costs, individual preferences, or other non-monetary influencing factors have not been considered. The research within this paper, as part of a two-stage survey study, adds to the field by analyzing individual's acceptance [2] and preferences of HEA for traveling in Europe based on recently collected empirical survey data. Our study also discusses the practical implications regarding market potentials of HEA, providing recommendations for relevant stakeholders.

The remainder of this paper is structured as follows: a review of the relevant market and demand studies regarding regional electric or hybrid-electric aircraft (Section 2). This is followed by an account of the methodologies applied in the study, including data collection and mode choice model development (Section 3). The subsequent section describes the survey sample before discussing the results (Section 4). The key findings are then interpreted and summarized (Section 5 and 6), and practical implications and recommendations are provided (Section 7). The final section presents our conclusions and provides an outlook on further research (Section 8).

2. LITERATURE REVIEW

To date, there is limited research focusing on analyzing the market potentials of regional and short-haul fully- or hybrid-electric airplanes. Most recently, Justin et al. [5] conducted a market study covering the entire United States on a county level. Using a four-step demand model and fleet optimization, the authors quantified and assessed the demand for electric and hybrid-electric aircraft operated between 100 and 350 miles. They uncovered the demand for regional air mobility services that cannot be met by the current commuter operators who can serve between 10 and 75 passengers per day. And they concluded that regional air mobility operators could profitably serve about half of the estimated demand. Spangenberg et al. [6] conducted a market study for 19-passenger hybrid-electric commuter aircraft as part of the ELICA Project. The results showed an estimated market share of 5% and 15% for Europe and the USA, respectively, with a focus on business travelers. In addition, regional air mobility with an average mission distance between 100 and 400 km and thin-haul air cargo services have been identified as two promising market segments. In a case study of Italy, Salucci et al. [7] compared the travel times of 19-seater HEA and ground-based transport modes and optimized the network to capture the highest travel demand. The results showed that up to 15,000 daily commuters could benefit from the point-to-point service with trip distances between 40 and 300 km. Grimme et al. [8], Paproth et al. [9] and Baumeister et al. [10] compared hybrid-electric or electric aircraft with other transportation modes in terms of travel time saving and emission reduction benefits. Regarding the German market, Grimme et al. [8] revealed that travel time savings of regional 19-seater HEA could occur at distances up to 400 km, given the aircraft's maximum mission distance of 200 km. The highest travel time savings can be achieved for connections between major cities and between secondary metropolitan areas that are not well connected by rail or road and with a distance of 300 to 400 km in between. Also focusing on Germany and comparing travel times and costs, Paproth et al. [9] predicted a preliminary market share of 6 % of thin-haul air mobility services. 30 % of the trips were estimated to be between only 20 airports. Baumeister et al. [10] compared the emissions and travel times of 9-19 seater full-electric aircraft and ground-based transport modes (car and trains) in Finland. The authors found that electric aircraft could replace existing cars and trains on distances beyond 170 km and high-speed trains beyond 400 km if electricity is generated from renewable energy sources.

Nevertheless, none of the market or demand studies mentioned above focused on passengers' behavior, preferences, or willingness to adopt electric or hybrid-electric aircraft. We filled this research gap by analyzing mode choice behavior and predicting market potentials of regional air transport enabled by new propulsion technologies and renewable energy sources, based on empirical survey data.

3. METHODOLOGY

We collected and analyzed survey data due to the fact that no empirical passenger data were available to analyze the adoption and preference of regional commuter aircraft in Germany. In the following sections, we first present the design of the survey instrument, followed by the development of the mode choice model.

3.1. Data collection

To understand the market potential of 19-seater commuter aircraft in Germany focusing on passenger preference, we designed travel-purpose-based stated preference (SP) surveys (available in German) and distributed them online via a commercial digital survey panel to obtain representative samples. From October 2022 to April 2023, we collected data from a representative sample of 2,523 private travelers who had traveled for leisure or other private purposes and 595 business travelers who had traveled within Europe starting from Germany before the restrictions of COVID-19 started. We decided to recruit panelists who were at least 18 years old for this study.

The survey regarding private travel was first designed and implemented. It was structured in five parts. The first part screened eligible participants by asking if they had ever traveled between 300 and 950 km (one-way) from Germany to a destination within Europe in 2019. The travel range was defined considering the potential competitive and maximum operation range of HEA [1, 3, 8]. We also included questions on gender, age, highest education level, household income, and residential area in this section to ensure that the participant quota corresponded to the population distribution. The second part elicited more details about a typical trip a respondent had traveled, such as travel distance, origin and destination, travel purpose, duration, and transport mode, etc. The third section was the core part of the survey where we provided detailed scenarios of service features of typical 19-seater commuter aircraft and hypothetical choice questions regarding a future trip similar to the reported trip in terms of travel distance, purpose, and duration. The details regarding the design of choice questions are presented in the following section. The questions included in the fourth section were designed to measure attitudes toward using new mobility products and climate change. The survey ended with questions capturing other demographic information, such as employment status, household composition, driver's license, car availability, and postal code. In addition, a few quality control questions were added to control for the data quality.

The business travel survey followed the aforementioned structure and was distributed following the completion of data collection of the private travel survey. To better understand business travel behavior, we focused more on employment characteristics, such as the type of employers and their business travel policies, assuming that the employers' policies played an essential role in business travel decision-making. Additionally, we included a MaxDiff question (Maximum Difference Scaling or best-worst scaling) [11] to rank the relevant service attributes to complement the stated choice questions.

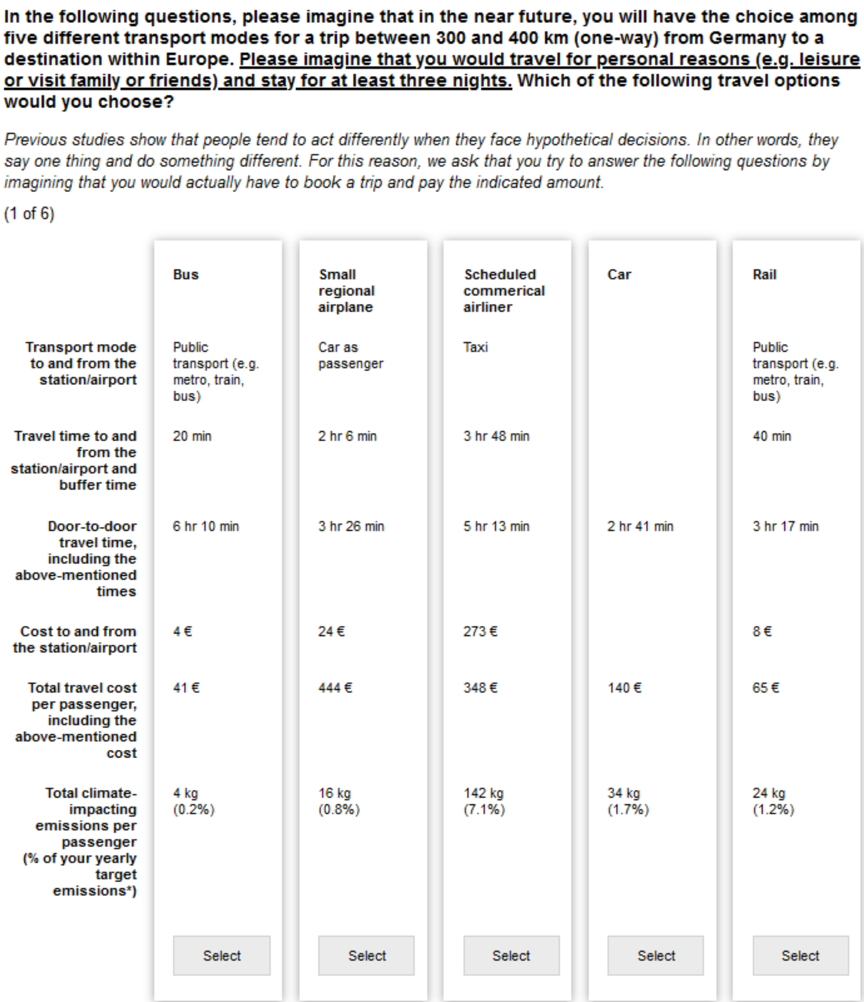
Details of survey items regarding attitudes and organizational business travel policies can be found in Appendix 3 and Appendix 4.

3.1.1. Stated choice experiment

In the survey regarding private travel, each respondent was asked to complete six choice tasks and select the most preferred option among five intermodal transport alternatives considering travel time, travel cost, CO_2-eq emissions, and means to travel to/from airport or station. We individualized the question by asking respondents to imagine a future trip with the same trip distance range, purpose, and duration as reported. Each respondent received a unique version of the choice tasks generated using random design strategy [12]. Six attributes were defined to specify each of the five transport mode alternatives, including car, rail, long-distance bus, kerosene-fueled commercial airliners, and 19-seater commuter aircraft. An additional alternative *None of the above* was also included, allowing respondents to indicate that no offering is sufficiently attractive. To understand the preference of both conventional and hybrid-electric configurations, we randomly assigned the "conventional" scenario where 19-seater conventional aircraft (the reference configuration) was one of the options to half of the respondents and the "HEA" scenario where HEA 19-seater was one of the alternatives to the other half. Figure 1 presents an example choice task of the "HEA" scenario for a distance range between 300 and 400 km. The attributes were defined as follows:

- **Transport mode to and from the station/airport** indicates the transport modes that will be used to travel from the origin to the station/airport and from the station/airport to the final destination.
- **Time of traveling to and from the station/airport** indicates the time it takes to travel from the origin to the station/airport and from the station/airport to the final destination.
- **Cost of traveling to and from the station/airport per passenger** indicates the costs per passenger to travel from the origin to the station/airport and from the station/airport to the final destination.
- **Door-to-door travel time** indicates the time it takes to travel between origin and destination. For rail and bus, it includes both main mode travel time and travel time to and from the station. For air modes, it includes flight time, time of traveling to and from the airport, and pre-boarding and transition time after arrival.
- **Total travel cost per passenger** indicates the total travel expenses per passenger for the entire trip, including travel by the main mode and travel to and from the station/airport.
- **Total CO_2-eq emissions per passenger** indicates the total CO_2-eq emissions per passenger for the entire trip, including travel by the main mode and travel to/from the station/airport. The emissions were presented in both specific values and percentage of individual yearly target emissions defined by Intergovernmental Panel on Climate Change (IPCC).

The calculations of travel time, cost, and CO_2-eq emissions emissions were based on origin-destination (OD) pairs at the NUTS3 level between Germany and other countries within Europe. To present different choice scenarios, each attribute has multiple levels including a pre-defined reference level, as well as lower and higher levels pivoted based on the reference level. As mentioned above, the trip consisted of three legs - the first mile, the main mode of travel, and the last mile.



In the following questions, please imagine that in the near future, you will have the choice among five different transport modes for a trip between 300 and 400 km (one-way) from Germany to a destination within Europe. Please imagine that you would travel for personal reasons (e.g. leisure or visit family or friends) and stay for at least three nights. Which of the following travel options would you choose?

Previous studies show that people tend to act differently when they face hypothetical decisions. In other words, they say one thing and do something different. For this reason, we ask that you try to answer the following questions by imagining that you would actually have to book a trip and pay the indicated amount.

(1 of 6)

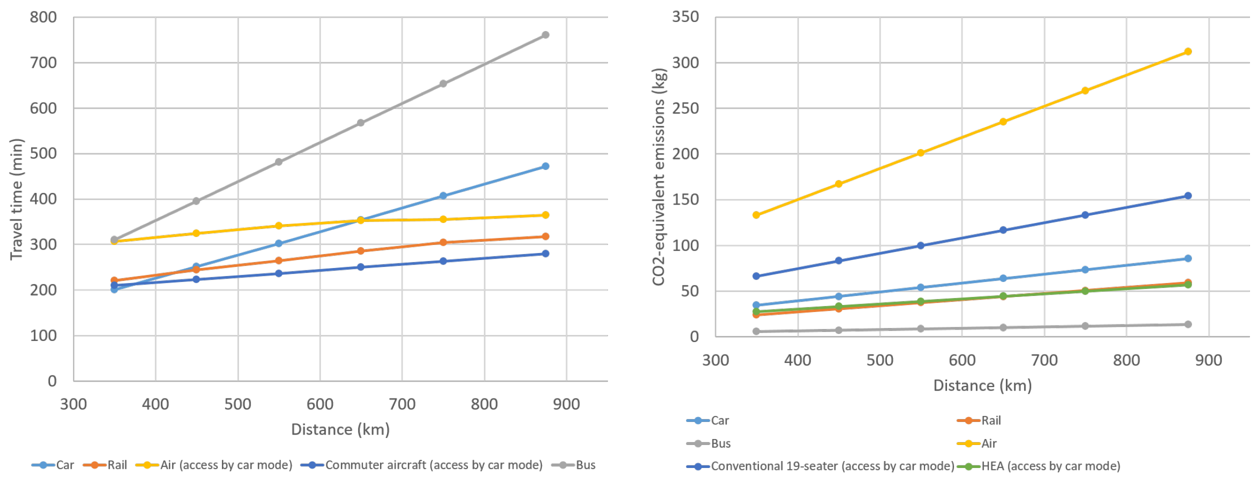
	Bus	Small regional airplane	Scheduled commerical airliner	Car	Rail
Transport mode to and from the station/airport	Public transport (e.g. metro, train, bus)	Car as passenger	Taxi		Public transport (e.g. metro, train, bus)
Travel time to and from the station/airport and buffer time	20 min	2 hr 6 min	3 hr 48 min		40 min
Door-to-door travel time, including the above-mentioned times	6 hr 10 min	3 hr 26 min	5 hr 13 min	2 hr 41 min	3 hr 17 min
Cost to and from the station/airport	4 €	24 €	273 €		8 €
Total travel cost per passenger, including the above-mentioned cost	41 €	444 €	348 €	140 €	65 €
Total climate-impacting emissions per passenger (% of your yearly target emissions*)	4 kg (0.2%)	16 kg (0.8%)	142 kg (7.1%)	34 kg (1.7%)	24 kg (1.2%)
	Select	Select	Select	Select	Select

FIG 1. Example of a stated choice question

The travel times of the main mode of travel were calculated based on the average distance of six pre-defined distance ranges (300 - 400 km, 400 - 500 km, 500 - 600 km, 600 - 700 km, 700 - 800 km, and 800 - 950 km) and the distance-based average travel speed derived from [13] for car, rail, and bus, and [14] for commercial airliners. Regarding both types of commuter aircraft, we used the reference block time was calculated based on a result of GNOSIS project $y = 0.0041x + 0.4333$, where x is the distance (NM) and y is the corresponding block time (hours) [4]. The lowest and highest levels were pivoted 10% around the reference level.

The travel times of the first and last miles for ground modes were defined according to the travel means and the values were taken mostly from existing studies. The definition of time traveling to or from the airport for air modes was based on Google distance matrix API. All the first miles were assumed to be starting from an origin within Germany to 132 considered German airports for commuter aircraft (28 airports for current kerosene-fueled commercial airliners). As the destination could be anywhere within Europe, the travel times of the last miles were estimated based on an average of five selected countries, including Germany, France, UK, Italy, and Sweden. We applied an algorithm to find the nearest airport for all origins and destinations based on Euclidean distance and obtained the distances and travel time to/from these airports weighted by the population density of NUT3 regions. We then derived an average of 66 minutes to travel to/from airport for commuter aircraft (88 minutes for commercial airliners). In addition, we assumed a 40-minute pre-boarding time and 20-minute transition time after arrival for a trip with commuter aircraft, compared with a 75-minute pre-boarding and 30-minute transition for conventional commercial airliner [10].

The trip cost for ground modes were calculated for the entire door-to-door trip, based on the cost per km derived by [13]. The cost for conventional commercial airliners were retrieved from [15]. Regarding both types of commuter aircraft, the reference ticket price was projected to be between 0.45 and 0.6 € per Revenue Passenger Kilometer (RPK) which is similar to the ticket price of German first-class train [16]. 0.45 and 0.6 € were set as the lowest and highest level, respectively. The costs of the first and last miles for air modes were calculated based on the distances of first- and last-mile travels calculated from Google distance matrix API, following the aforementioned calculations,



(a) Travel times of transport alternatives

(b) CO_2-eq emissions of transport alternatives

FIG 2. Baseline travel times and emissions defined in the choice questions

as well as different transport modes providing the services.

The trip emissions for ground modes and conventional commercial airliners were calculated for the entire door-to-door trip, based on the cost per km derived by [13]. The emission levels were set differently between the two commuter aircraft configurations, assuming that the emission of 19-seater HEA was substantially lower than that of the 19-seater conventional aircraft in case HEA's power is generated from the green electricity. The best scenario regarding the life cycle emissions of HEA 19-seater was calculated as 30 g CO_2-eq per passenger km, assuming an emission reduction between 66% and 82% in 2050 compared with the emissions of the reference aircraft [4]. Similarly, the emissions of the first and last miles were calculated depending on the aforementioned first- and last-mile distances and different transport means.

Figure 2 shows the defined baseline (reference) values of travel time and CO_2-eq emissions of all transport alternatives. A completed overview of attribute levels based on distance range is summarized in Appendix 1 and Appendix 2.

The stated choice questions in the business travel survey were designed in the same manner as the ones in the private travel survey, except that we removed the "time of traveling to/from airport or station" and "cost of traveling to/from airport or station" as their impacts seemed to be trivial according to the results of private travel survey. The reduction of the attribute was also expected to reduce the burden of respondents when filling out the questionnaire. In addition, car and taxi were added as two additional options for first- and last-mile of rail and bus alternatives for business travelers.

3.2. Model development

Based on collected data, a transport mode choice model was developed based on a multinomial logit model (MNL) to analyze how the respondents' choices are influenced by the relevant service attributes (travel time, travel cost, and emissions) and their personal or household characteristics (demographics and travel behavior). We calculated the utility of a transport mode option to indicate its attractiveness based on Equation (1). Assuming that the utilities of existing transport modes (ground modes and kerosene-fueled commercial airliners) remained the same across two scenarios ("conventional 19-seater" and "HEA 19-seater" mentioned in 3.1.1, we merged the data sets of two scenarios into one data set by introducing a binary variable to differentiate two configurations of commuter aircraft, making it possible to compare the utility of all six transport alternatves. Meanwhile, considering that passengers' mode preferences differed across distances and the findings from previous studies that passengers' willingness to pay for flights depends on the flight duration (short-haul vs. long-haul) [17, 18], we fitted the model to two data subsets regarding short and long distances. Later, based on the calculated utility, the probability of selecting each alternative was estimated at the maximum likelihood according to Equation (2). More detailed theoretical foundation underlying these models is provided in e.g. [19, 20]. The models were estimated with the Apollo package in R [21].

(1) $$U_{iq} = V(X_{iq}) + V(S_q) + ASC_{iq} + \varepsilon_{iq},$$

where U_{iq} is the utility of the ith alternative for the qth individual; $V(X_{iq})$ is systematically derived element of the ith alternative for person q (such as travel time); $V(S_q)$ is the portion of utility related to characteristics of individual q (such as income); ASC_{iq} is the alternative-specific constant for alternative i; ε_{iq} is an error term.

(2) $$P_{iq} = \frac{\exp(V_{iq})}{\sum_{j=0}^{J} \exp(V_{jq})},$$

where P_{iq} is the probability of selecting alternative i; V_{iq} is a systematic component of the utility of alternative i; V_{jq} is a systematic component of the utility of alternative j.

4. RESEARCH SAMPLE

The sample consisted of 2,523 private travelers and 595 business travelers, respectively, for the two surveys, which well represented the two travel segments compared with the results of the German household travel survey 2017 (MiD 2017 [22]). Due to the quota-based sampling, the sample of private travelers was very representative in terms of gender, age, educational level, household income, and region, as shown in Table 1. The gender and age distributions corresponded to the German census [23]. Distributions of income and education were comparable to the statistics from the Federal Statistical Office database [24]. To ensure a representative sample of urban, suburban, and rural areas, we sampled based on postal codes categorized according to area type, defined by the Federal Institute for Research on Building, Urban Affairs, and Spatial Development [25].

Due to the challenge of reaching business travelers in general, quotas of social demographics were not applied for sampling. All travelers who have traveled for business within Europe were eligible to participate in the survey. Table 2 shows that the distributions of gender and age followed a similar pattern as that in the MiD 2017. In our sample, almost half of the respondents were employees of large companies, followed by local small to medium-sized enterprises (SME). Meanwhile, the majority of the respondents had traveled at least once per year during the pre-COVID period. Most of these business trips had been fully financially covered by the employers. In addition, more than 70% of the employers have already implemented at least one sustainable business travel policy.

TAB 1. Sample characteristics of private travelers

Category	Sample distribution (N = 2523) (%)	Population distribution (%)
Gender		
Male	49.1%	48.6%
Female	50.9%	51.4%
Age (years)		
18-25	6.8%	9.2%
26-35	17.7%	21.7%
36-45	23.1%	22.4%
46-55	23.4%	22.2%
56-65	19.7%	16.8%
>65	9.3%	7.7%
Region		
Urban	35.7%	31.0%
Suburban	38.8%	44.0%
Rural	25.5%	25.0%
Education level completed		
School without graduation	0.1%	1.0%
Primary or secondary school	14.7%	23.0%
High school - Abitur	13.7%	12.0%
Apprenticeship	46.1%	40.0%
University/higher education	25.3%	24.0%
Annual household income (€)		
€ 0 - 13,000	13.8%	11.0%
€13,000 - 19,499	9.9%	14.0%
€19,500 - 38,999	34.5%	38.0%
€39,000 - 64,999	28.7%	25.0%
More than €65,000	13.1%	12.0%

Note: Abitur = high-school diploma

TAB 2. Sample characteristics of business travelers

Category	Sample distribution (N = 595) (%)	MiD 2017 distribution (%)
Gender		
Male	63.2%	80%
Female	36.5%	20%
Diverse	0.3%	NA
Age (years)		
18-25	5.0%	19 % (18 - 29)
26-35	25.0%	25 % (30 - 39)
36-45	28.7%	28 % (40 - 49)
46-55	25.0%	22 % (50 - 59)
56-65	16.1%	4 % (60 - 64)
Type of employers		
local, small to medium-sized enterprise (<250 employees)	28.6%	NA
international, small to medium-sized enterprise (<250 employees)	10.9%	NA
large German company (headquarter in Germany)	31.9%	NA
large international company (branch in Germany)	15.3%	NA
public service (educational institution, public administration, hospital or similar)	9.7%	NA
others	3.5%	NA
Frequency of business travel before COVID-19		
at least once a month	12.1%	NA
6 to 11 times a year	16.0%	NA
3 to 5 times a year	31.3%	NA
1 to 2 times a year	29.4%	NA
less than once per year	4.4%	NA
not at all	5.9%	NA
NA	1.0%	NA
Reimbursement of travel expenses		
Yes	86.9%	NA
Partial	5.5%	NA
No	7.6%	NA
Implementation of sustainable business travel policies		
Yes (at least one policy from the list or not on the list is implemented)	72.4%	NA
No	27.6%	NA

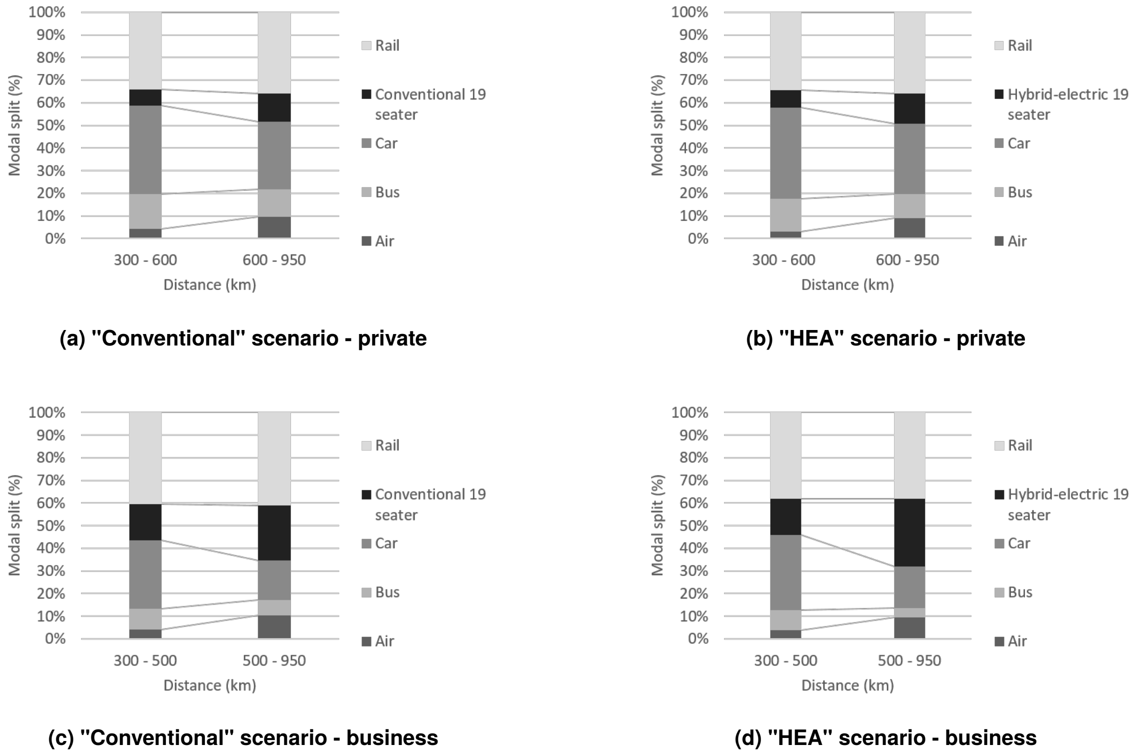
Note: NA = not available

5. RESULTS AND DISCUSSION

This section provides the main findings regarding the reported transport mode share based on descriptive statistics and passenger preferences and demand sensitivities implied by the statistical models. Then, we further discuss the implications of these results.

5.1. Reported mode share

Figure 3 depicts the mode share calculated based on the stated mode choice under 19-seater conventional commuter and 19-seater HEA scenarios for private and business travelers. Generally, car and rail were the most frequently selected modes for private travelers. For longer routes above 600 km, we saw a tendency of modal shift from ground-based modes to air modes. Private travelers preferred both types of commuter aircraft over kerosene-fueled commercial airliners at all distances. The shares of commuter air-



(a) "Conventional" scenario - private

(b) "HEA" scenario - private

(c) "Conventional" scenario - business

(d) "HEA" scenario - business

FIG 3. Reported mode share

craft also overtook that of long-distance bus for longer routes.

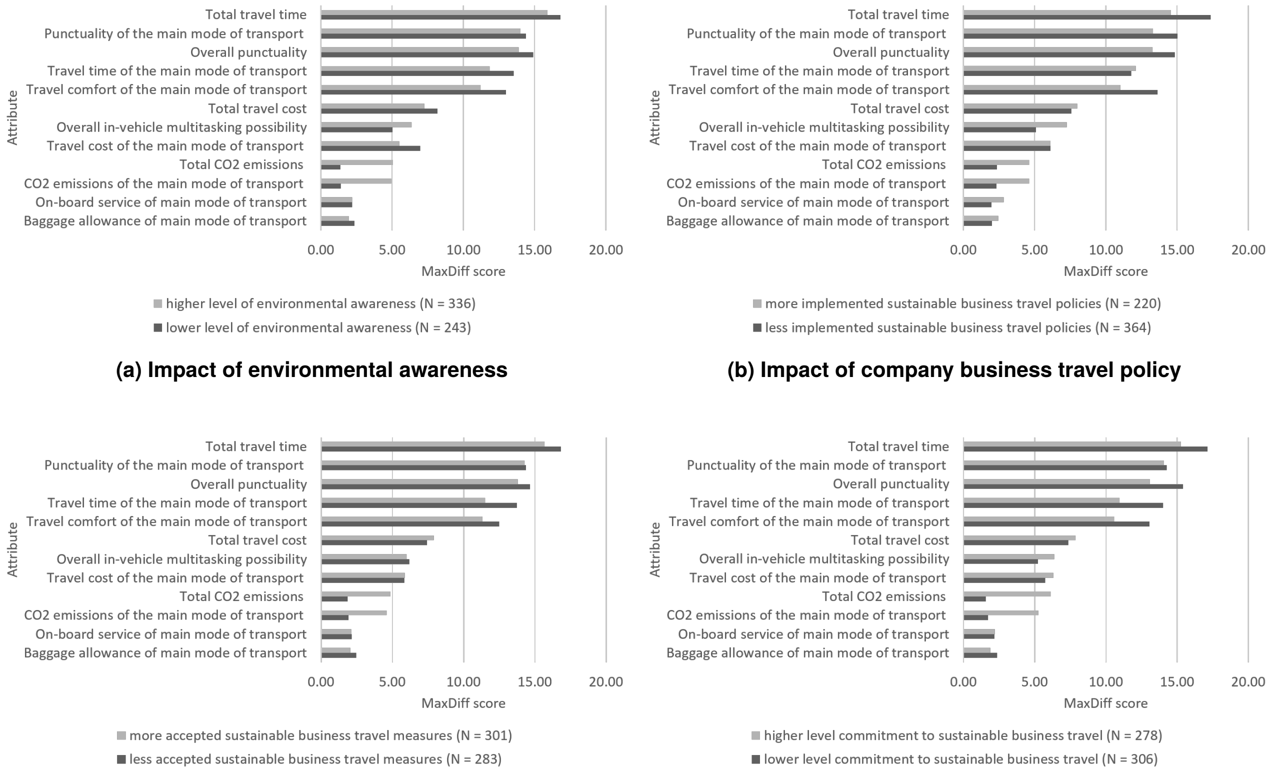
A different modal choice situation was seen in the business travel market. Rail was the most frequently selected mode at all distances, followed by car for shorter routes less than 500 km. A more dramatic modal shift from ground to air was seen between shorter and longer routes. Here, the shares of both types of commuter aircraft overtook that of kerosene-fueled commercial airliners and all ground modes except for rail. HEA 19-seater also became more attractive in this distance segment, gaining one-third of the market share.

In the private travel market, the 19-seater conventional commuter gained 7% market share while the 19-seater HEA gained 8%. These shares were slightly higher than the 5% found by [6] and 6% showed by [9]. 19-seater conventional commuter and HEA gained higher share at longer distances, reaching 13% and 14%, respectively, in the private travel market, and 25% and 30%, respectively, in the business travel market. The higher share gained in the business travel market was likely due to more substantial travel time savings (see more details in Section 5.3). This implies that a sufficient aircraft operation range, intermodal integration, and efficient airport procedures must be ensured to maintain the competitiveness of commuter aircraft. In our case study, the maximum operation range of the HEA 19-seater was defined as 950 km. However, for other aircraft configurations, such as battery-powered electric aircraft with a limited operation range of up to 400 km, additional transfer and layover times need to be considered as they might diminish the travel time-saving potentials and, therefore affect the passenger preferences. In addition, as the rail shares remained relatively large and stable at all distances, the air-rail competition was not seen based on the SP data in our study.

5.2. Attribute importance

Before investigating how the aforementioned attributes affected the mode choice, we briefly summarize how these attributes were identified. In a previous study [2], we found that travel time, cost, and emissions were among the top factors affecting passengers' mode choice decisions. More specifically, business travelers perceived time-related attributes (such as punctuality and efficient procedure at the airport) as more important than cost and vice versa for private travelers. We considered business travelers as the potential early adopters of the regional services provided by commuter aircraft due to their lower sensitivity to price, at least during the market entry stage.

In this survey, we analyzed how business travelers perceived the importance of attributes using a MaxDiff method, which differed from the method we implemented in the previous survey. As seen in Figure 4, similar to the results of the previous survey, travel time, punctuality, and comfort were perceived as most important. Most interestingly, we found that individuals who were more environmentally aware and supported sustainable business travel policies in the company tended to pay more attention to travel emissions compared with the others. Previous studies [26, 27] found that business travel behaviors



(a) Impact of environmental awareness **(b) Impact of company business travel policy**

(c) Impact of acceptance of business travel measures **(d) Impact of commitment to sustainable business travel**

FIG 4. Attribute importance for business travelers

can be strongly affected by institutional travel policies. Business travelers may follow the organizational norms instead of considering their individual values and attitudes [28]. In fact, around 40% respondents indicated that at least one sustainable business travel policy has already been implemented in the company or organization. Meanwhile, around half of the respondents tended to accept or support these measures. This implies that company or organization travel policies could be a strong lever for the adoption of lower-emission transport modes for business travel.

5.3. Willingness to pay (WTP) and user characteristics

Willingness-to-pay (WTP) is a monetary measurement of the marginal rate of substitution (MRS) at which consumer has to give up the consumption of another good to increase one unit of one good [19]. In our case, it was used to measure the trade-off between two service attributes of a transport mode. For example, while keeping the utility of a transport mode unchanged, when the travel time is reduced by one unit, WTP (between travel time and ticket price) measures the cost that passengers are willing to pay. Based on trip purposes and travel distances, Table 5 shows the calculated individuals' WTP for travel time savings and emission reductions for all six intermodal transportation alternatives, based on the statistically significant coefficients of total travel time, total CO_2-eq emissions, and total travel cost shown in Table 3 and Table 4, following Equation 3.

$$\text{WTP} = -\frac{\beta_{i,\text{attribute}}}{\beta_{i,\text{cost}}}, \tag{3}$$

where $\beta_{i,\text{attribute}}$ is the estimated coefficient of an attribute of ith alternative; $\beta_{i,\text{cost}}$ is the estimated coefficient of the cost of ith alternative.

Generally, there were more significant results of WTP for travel time savings than WTP for emission reductions in both private and business travel. This was consistent with the findings that travel time and ticket price were perceived as more important than emissions [2]. For saving travel times, business travelers tended to be willing to pay more than private travelers for all transport options at all distances. This finding were in line with other WTP studies, such as [29] and [30]. Another general trend was the decrease of WTP at longer distances (except for air in private travel and rail in business travel). Addressing commuter aircraft, private travelers stated a WTP of 1.63 € to save one-minute door-to-door travel time (or 97.8 € to save one-hour travel time) for 19-seater conventional commuters for shorter distances up to 600 km. In contrast, business travelers stated significantly higher WTP of 3.01 € to save one minute (or 180.6 € for one hour) and 2.46 € to save one minute (or 147.6 € for one hour) for using conventional and hybrid-electric 19-seater, respectively, for longer-distance business trips above 500 km. The estimated WTP was in a similar magnitude as the findings on WTP for regional aviation by regional airlines in Australia [31]. Such substan-

TAB 3. MNL model estimation for private travel purpose

Coefficient (β)	Car	Rail	Bus	Air	Conv. 19-seater	HEA 19-seater
ASC_short	-1.33*** (0.38)	0.23 (0.27)	Base case	-3.14*** (0.67)	-3.03*** (0.66)	-3.84*** (0.38)
ASC_long	-0.47 (0.40)	2.47*** (0.24)	Base case	-0.39 (0.51)	-1.62*** (0.36)	-1.29*** (0.35)
Total travel time_short	-0.47*** (0.06)	-0.48*** (0.03)	-0.45*** (0.06)	-0.24* (0.11)	-0.51* (0.26)	NS
Total travel time_long	-0.18** (0.05)	-0.38*** (0.03)	NS	-0.37*** (0.10)	NS	NS
Total travel cost_short	-0.42*** (0.06)	-0.72*** (0.08)	-0.96*** (0.25)	-0.28*** (0.06)	-0.32*** (0.06)	-0.30*** (0.05)
Total travel cost_long	-0.21*** (0.06)	-0.62*** (0.07)	-0.97*** (0.21)	-0.43*** (0.05)	-0.27*** (0.04)	-0.31*** (0.05)
Total CO_2-eq emissions_short	NS	NS	NS	-0.57* (0.28)	NS	NS
Total CO_2-eq emissions_long	NS	-0.57* (0.23)	NS	NS	NS	NS
Annual household net income						
(reference: up to 65,000 €)						
more than 65,000 €	0.40** (0.14)	0.40** (0.14)	Base case	0.59** (0.19)	0.42 (0.22)	0.59** (0.19)
Age						
(reference: older than 45 years old)						
18 to 45 years old	NS	0.10 (0.07)	Base case	0.75*** (0.13)	0.39*** (0.10)	0.39*** (0.10)
Education						
(reference: up to high school degree)						
high school degree or above	0.39*** (0.10)	0.20* (0.08)	Base case	NS	0.29 (0.16)	NS
Type of residential area						
(reference: non-urban)						
urban	-0.20* (0.09)	NS	Base case	0.40** (0.13)	0.19 (0.14)	0.24 (0.14)
Interest in new mobility technology						
(reference: less interested)						
more interested	-0.51*** (0.09)	NS	Base case	0.31** (0.11)	0.67*** (0.14)	0.31** (0.11)
Climate concern						
(reference: less concerned)						
more concerned	-0.63*** (0.08)	NS	Base case	-0.33* (0.13)	-0.45** (0.14)	NS
Car availability						
(reference: no)						
yes	2.13*** (0.21)	NS	Base case	1.19*** (0.16)	1.19*** (0.16)	1.19*** (0.16)
Travel frequency						
(reference: less than 1 - 2 times per year)						
at least 1 - 2 times per year	0.28* (0.13)	0.15 (0.11)	Base case	0.43* (0.20)	0.62** (0.21)	0.28* (0.13)
Trip duration						
(reference: stay three nights and above)						
stay up to three nights	0.31** (0.09)	NS	Base case	NS	NS	0.28 (0.17)
Other information						
No. of observations	11950		No. of parameters			59
Initial LL	-19232.78		Final LL			-14885.19
Adjusted Rho-squared	0.223		AIC			29888.38
BIC	30324.31					

Note: Coefficient: estimated values (standard errors);NS = not significant; ASC = alternative specific constant; Significant values are marked by * (p-value < 0.05), ** (p-value < 0.01), and *** (p-value < 0.001); LL = log-likelihoods; AIC = Akaike information criterion; BIC = Bayesian Information Criterion; Conv. 19-seater = Conventional 19-seater; Emissions of car and bus were not estimated intentionally due to the high correlation between travel time and emissions for car and bus.

TAB 4. MNL model estimation for business travel purpose

Coefficient (β)	Car	Rail	Bus	Air	Conv. 19-seater	HEA 19-seater
ASC_short	-0.80 (1.37)	-0.66 (1.07)	Base case	0.04 (2.10)	-5.63*** (1.18)	-2.74* (1.29)
ASC_long	0.39 (1.22)	2.77** (0.91)	Base case	1.57 (1.14)	0.02 (1.36)	2.31 (1.33)
Total travel time_short	-1.54*** (0.18)	-0.84*** (0.10)	-0.91** (0.26)	-0.51 (0.30)	NS	NS
Total travel time_long	-0.58*** (0.13)	-0.68*** (0.06)	-0.20 (0.13)	-0.50** (0.17)	-0.74* (0.35)	-0.90* (0.33)
Total travel cost_short	-0.45* (0.19)	-0.56** (0.19)	-1.87** (0.55)	-0.37** (0.14)	-0.34*** (0.09)	-0.56*** (0.11)
Total travel cost_long	-0.26* (0.12)	-0.40*** (0.11)	-0.67* (0.28)	-0.42*** (0.07)	-0.24*** (0.04)	-0.36*** (0.05)
Total CO_2-eq emissions_short	NS	NS	NS	-2.64* (1.13)	NS	-4.19 (2.38)
Total CO_2-eq emissions_short (stronger commitment to sustainable business travel)	NS	NS	NS	1.22** (0.37)	NS	NS
Total CO_2-eq emissions_long	NS	-0.59 (0.41)	NS	NS	NS	NS
Monthly personal net income (reference: less than 6000 €)						
at least 6000 €	NS	NS	Base case	NS	0.52** (0.17)	0.52** (0.17)
Age (reference: older than 45 years old)						
18 to 45 years old	-0.40* (0.19)	-0.50** (0.15)	Base case	NS	NS	NS
Car availability (reference: no)						
yes	2.34*** (0.59)	NS	Base case	NS	NS	1.10* (0.56)
Travel frequency (reference: less than 1 - 2 times per year)						
at least 1 - 2 times per year	NS	NS	Base case	NS	1.05* (0.48)	NS
Trip duration (reference: stay three nights and above)						
stay up to three nights	NS	0.52** (0.16)	Base case	NS	0.75** (0.25)	NS
Company size (reference: small company or public sector)						
big company with more than 250 employees	NS	NS	Base case	NS	0.57* (0.23)	NS
Reimbursement of travel expenses (reference: not fully reimbursed)						
fully reimbursed	0.85** (0.28)	0.85** (0.28)	Base case	1.60*** (0.35)	1.60*** (0.35)	1.04* (0.45)
Implementation of sustainable business travel policies in the company (reference: less implemented)						
more implemented	-0.82*** (0.18)	NS	Base case	NS	NS	NS
Level of individual commitment to sustainable business travel (reference: lower level)						
higher level	-0.61*** (0.17)	NS	Base case	-1.22*** (0.28)	-0.61*** (0.17)	-0.52* (0.21)
Other information						
Number of observations	2904		No. of parameters			52
Initial LL	-4673.81		Final LL			-3455.22
Adjusted Rho-squared	0.2496		AIC			7014.45
BIC	7325.09					

Note: Coefficient: estimated values (standard errors);NS = not significant; ASC = alternative specific constant; Significant values are marked by * (p-value < 0.05), ** (p-value < 0.01), and *** (p-value < 0.001); LL = log-likelihoods; AIC = Akaike information criterion; BIC = Bayesian Information Criterion; Conv. 19-seater = Conventional 19-seater; Emissions of car and bus were not estimated intentionally due to the high correlation between travel time and emissions for car and bus.

TAB 5. Calculation of willingness-to-pay

(a) Willingness-to-pay regarding door-to-door travel time savings (€ /minute)

	Private		Business	
	Short (<= 600 km)	Long(>600 km)	Short (<= 500 km)	Long(>500 km)
Car	1.12	0.85	3.39	2.26
Rail	0.66	0.61	1.50	1.71
Bus	0.46	NA	0.49	0.30
Air	0.86	0.86	1.38	1.18
Conventional 19-seater	1.63	NA	NA	3.01
HEA 19-seater	NA	NA	NA	2.46

(b) Willingness-to-pay regarding door-to-door CO_2-eq emissions reduction (€ /kg)

	Private		Business	
	Short (<= 600 km)	Long(>600 km)	Short (<= 500 km)	Long(>500 km)
Car	NA	NA	NA	NA
Rail	NA	0.92	NA	1.48
Bus	NA	NA	NA	NA
Air	2.03	NA	7.06	NA
Conventional 19-seater	NA	NA	NA	NA
HEA 19-seater	NA	NA	7.48	NA

Note: NA = not available

tial contrast between these two user segments could be explained by two main reasons. First, evidence from our and other studies indicated that compared with private travelers, business travelers were much more sensitive to travel times. Second, as the cost of the majority of the business travels was covered by the employers, employees traveling on business might consider the nature of their travel as being outside of their responsibility to control it [32]. Therefore, travel costs tended to be less relevant for business travelers.

Concerning WTP for emissions reduction, both private and business travelers stated WTP for air in shorter distances and rail in longer distances. It was in line with a recent findings on a general trend that travelers will pay extra for sustainable travel despite inflation [33]. Again, a much higher WTP of business travelers was found. The findings on WTP for air travel emission reduction confirmed the previous findings regarding WTP for carbon offsets (such as [17, 34]) and for flying with aircraft using alternative fuels and new propulsion systems (such as [35–37]). Lu et al. [38] further claimed that compared to non-business passengers, business travelers are willing to pay more for the offsets if their travel costs were subsidized. In addition, we also found that business travelers with a stronger commitment to sustainable business travel tended to pay more attention to the emission levels when choosing flying with conventional kerosene-fueled airliners. To determine the impact of emissions on the adoption of HEA 19-seater, we defined three emission scenarios (between 66% and 82%) for HEA 19-seater regarding each distance range. As a result, we found no significant WTP for emission reductions from private travelers (although they are willing to pay for emission reductions for short-haul flight with kerosene-fueled airliners), but a WTP of 7.48 € stated by business travelers to reduce 1 kg of total door-to-door CO_2-eq emissions for short-haul flight. However, so far we have not found any empirical data to validate this value regarding intermodal travel for business travelers. In addition, the large standard error regarding impacts of emissions for air and HEA 19-seater shown in Table 4 indicated a high level of uncertainties. A recent study [39] also revealed that air passengers might not be willing to pay as much as they stated regarding emissions. Therefore, we suggest a further investigation into this aspect in future studies.

The model estimation results shown in Table 3 and 4 also revealed the association between passengers' mode preferences and their socio-demographic characteristics. Among private travelers, higher-income and younger individuals tended to prefer air modes, including commuter aircraft, over ground modes. Individuals with stronger interests in new mobility technology were more likely to favor commuter aircraft. This might also explain the stronger preferences of younger passengers due to their openness to trying new technology [40, 41]. Passengers with stronger concerns about climate change showed a propensity to favor rail and 19-seater HEA, which are the lower-emission modes. Another main finding revealed was the preferences of air modes, especially the 19-seater conventional commuter of frequent travelers.

Business travelers whose business travel expenses were usually covered by their employers showed a strong preference of air modes for business purposes. Particularly, both commuter aircraft seemed to be more attractive than ground modes. The same association was found for higher-income individuals. Business travelers working in big companies and traveling frequently for short business trips were more likely to adopt 19-seater conventional commuter, however, such preference was not seen for 19-seater HEA, possibly due to the lack of trust towards new propulsion technology or other unobserved factors according to the finding from the previous survey [2]. In addition, those who indicated a stronger commitment to sustainable business travel tended to favor greener transport alternative rail, followed by HEA 19-seater.

5.4. Analysis of elasticity

Elasticity is an economic concept that measures the responsiveness of one variable to changes in another variable. To understand the demand sensitivities of each transport alternative to the change of relevant attributes, we calculated the elasticity of travel time, ticket price, and emissions for both private and business travelers. Equation 4 shows an example of the calculation of price elasticity. Table 6 shows the demand change in the percentage of all transport alternatives responding to 1% increase in total travel time, total travel cost, and total CO_2-eq emissions.

$$\text{Elasticity} = \frac{\%\Delta\text{Quantity}}{\%\Delta\text{Price}}, \tag{4}$$

where Δ is the change in quantity and price.

In general, compared with private travelers, business travelers were much more sensitive to travel time than the price for all transport modes, which confirmed the existing knowledge [42, 43]. Compared with travel time and cost, the demand was less sensitive to emissions due to its relatively low priority considered in mode choice decisions [2]. With a focus on commuter aircraft, 1% increase in ticket price led to 0.79% and 0.81% demand decrease for conventional 19-seater and HEA 19-seater, respectively. However, only 0.22% demand decrease and no change for two aircraft in case of 1% increase of travel time, meaning that the demand of both commuter aircraft was much more sensitive to price changes than time (speed) change for private travelers whose modal choice decisions were highly cost-driven. On the contrary, for business travelers, 1% increase in travel time increase caused 0.82% and 0.94% decrease in demand of conventional 19-seater and HEA 19-seater, respectively. In case of 1% price increase, 0.67% and 0.9% of the share would drop for conventional 19-seater and HEA 19-seater, respectively. It showed that the demand of both commuter aircraft was less responsive to price fluctuations but more sensitive to time (speed) change for business travelers. In both markets, HEA 19-seater seemed to have a slightly higher price sensitivity than conventional 19-seater. In addition, 1% increase in emissions resulted in 0.18% decrease of HEA demand. Here, we further confirmed that speed and price were still the main factors driving the adoption of commuter aircraft.

6. SUMMARY OF THE MAIN FINDINGS

Overall, we found that commuter aircraft, particularly HEA, were perceived as more attractive than conventionally kerosene-fueled airliners. For longer routes, the shares of commuter aircraft also overtook that of long-distance bus. A high mode share was estimated in the business travel segment, doubling the share foreseen in the private travel segment. Business travelers also indicated much higher WTP using HEA for saving travel times and reducing travel emissions, although the actual WTP for emission reduction is subject to further investigation due to high uncertainty. Travel comfort was revealed as another influential factor by the two-stage survey, following travel time (and travel-time-related attributes) and travel cost. Moreover, we found that business travelers whose travel expenses were reimbursed strongly preferred commuter aircraft. Business travelers with a stronger commitment to sustainable business travel favored greener transport alternatives like rail and HEA. The same association between individuals' climate concerns and preference of lower-emission modes (rail and HEA) was found in the private travel segment. Private travelers who were younger, with high income, frequent travelers, and interested in new mobility technology were likely to be the early adopters of commuter aircraft.

7. POLICY IMPLICATIONS BASED ON THE MAIN FINDINGS

In terms of relevance for manufacturers, operators, policymakers, and other decision-makers, we proposed the implications based on the main findings of the study.

First, the clear preference of commuter aircraft over kerosene-fueled commercial airliners and other ground modes indicates a promising market for commuter aircraft for regional air travel. The larger market shares of commuter aircraft and, particularly, HEA 19-seater, for distances above 500 km indicates a stronger adoption potential for relatively longer distance travel within Europe.

Moreover, it is evident that regional air transport enabled by commuter aircraft presents significant value to the business travel market, considering the relatively large market share and high WTP of business travelers for saving travel times using both types of 19-seaters and reducing emissions using 19-seater HEA. However, as business travelers tend to see stronger travel time-saving benefits for longer-distance travel, this implies generally that a sufficient operation range and a smooth and efficient battery recharging or swapping process would make electric aircraft competitive in the market as they

TAB 6. Demand elasticity

(a) Demand change of modes for private travel regarding 1% increase of travel time, ticket price, or CO_2-eq emissions (%)

	Travel time	Price	CO_2-eq emissions
Car	-0.56	-0.39	NA
Rail	-0.76	-0.33	-0.04
Bus	-0.98	-0.32	NA
Air	-0.97	-0.83	-0.36
Conventional 19-seater	-0.22	-0.79	NA
HEA 19-seater	NA	-0.81	NA

(b) Demand change of modes for business travel regarding 1% increase of travel time, ticket price, or CO_2-eq emissions (%)

	Travel time	Price	CO_2-eq emissions
Car	-1.70	-0.44	NA
Rail	-1.08	-0.24	-0.06
Bus	-2.02	-0.55	NA
Air	-1.53	-0.95	-0.53
Conventional 19-seater	-0.82	-0.67	NA
HEA 19-seater	-0.94	-0.90	-0.18

Note: NA = not available

directly affect the total travel time. Meanwhile, overall travel efficiency could also be improved by efficient airport procedures and seamless connections with first- and last-mile travels. In addition, a high level of travel comfort, including flight noise, bumpiness, and legroom, is another aspect with high expectations and expects attention from the manufacturers. Although the level of emissions is not the main decision driver, business travelers show a high WTP for reducing emissions. As the travel decisions of business travelers are usually affected by organizational travel policies, sustainable business travel policies are expected to be further promoted. The government is expected to support further Corporate Social Responsibility (CSR) strategies integrating sustainable business travel. Innovative business models could help promote the collaboration between airlines and ground-based mobility service providers to improve efficiency and comfort and reduce the carbon footprint of the entire intermodal travel chain.

In addition, our findings on WTP for emissions confirmed the trend that travelers are willing to pay extra for more sustainable travel [33]. Nevertheless, regarding the high uncertainty to understand the actual WTP for emissions, although we presented the travel emissions shown in percentage of the yearly targeted CO_2-eq emissions, respondents likely found it challenging to assess the real impact of a certain amount of emissions and thus difficult to make informed decisions. Methods are expected to properly quantify and illustrate the level of carbon footprint of using a transport mode. One proposed example by other researchers is eco-labels [44]. Baumeister et al. [45] found passengers' willingness to make trade-offs for the sake of green-labeled flights in terms of longer flight times. However, the study also addressed the risk of perceiving green-colored label as "green-washing". It is suggested that new eco-labels need to be communicated in a transparent and trustworthy manner.

8. CONCLUSION AND OUTLOOK

Regional commuter aircraft provide many opportunities, such as higher time efficiency in reaching regional airports. Enabled by electrification, HEA could contribute to the transition toward carbon neutrality if powered by renewable energy. To gain insights into passengers' transport mode preferences for long-distance travel in Europe and thus the adoption of regional air transport enabled by 19-seater HEA, we collected data via online SP surveys and analyzed valid responses from 2,523 private travelers and 595 business travelers. Based on the two estimated mode choice models, we predicted a promising market to introduce 19-seater HEA for longer-distance travel in Europe, especially for business travelers. Business travelers can be considered as early adopters as they indicated significantly higher WTP for saving travel times and reducing CO_2-eq emissions emissions. We suggested not only the need to improve travel speed, comfort, and environmental performance regarding aircraft design, but also the efficiency and sustainability in terms of operations of aircraft as well as other associated transport modes providing fist- and last-mile services.

We now identify some limitations of this study and suggest future research directions. First, so far, the WTP was derived from SP data, which might be associated with hypothetical bias due to the hypothetical nature of the stated choice experiment, meaning that there is a risk of overstating the WTP. Therefore, we plan to compare the stated WTP with the actual WTP values derived from revealed preference (RP) data, which could be validated using the existing travel data. Although no empirical data was available for evaluating the WTP for commuter aircraft, the validation of WTP regarding existing transport modes could provide some insights. Moreover, the defined attribute levels in the SP experiment concerning travel time and cost were more relevant to the connections between densely populated areas, which might not fully represent the travel conditions between remote areas. Future study is suggested to consider further analyzing the benefits that commuter aircraft could bring to these regions and how passengers would perceive them. As a next step, we plan to investigate further the impact of introducing HEA on modal shift and emissions change in our study area by simulating individual long-distance travels based on the developed mode choice model and taking into account the fleet and other supply aspects.

Despite the aforementioned limitations, this survey completed the two-stage survey-based study, providing a holistic view of factors affecting passenger acceptance and adoption of HEA. Generally, the most relevant service attributes identified are similar to what affects the passenger experience of flying with kerosene-fueled commercial airliners, showing the transferability of our findings to aircraft with larger capacity and longer operation ranges. Other findings concerning the WTP and impacts of attitudinal factors and individual characteristics also provide indications for decision-makers to target the potential market and promote the usage of eco-friendly aircraft.

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TAB Appendix 1. Attribute levels of SP experiment - private

Distance	Attribute	Car	Rail	Bus	Air	Conv. 19-seater	HEA 19-seater
	Access & egress mode	/	PT	PT	car;taxi; PT	car;taxi; ride-sharing	car;taxi; ride-sharing
	Access & egress time (minute)						
	by car/taxi/ride sharing	/	/	/	53; 88; 123	40; 66; 93	40; 66; 93
	by PT		20; 30; 40	20; 30; 40	140; 175; 245	/	/
	Access & egress cost (EUR)						
	by car	/	/	/	28; 38; 47	18; 24; 30	18; 24; 30
	by taxi				97; 149; 273	63; 96; 176	63; 96; 176
	by ride sharing				/	4; 8; 12	4; 8; 12
	by PT		4; 5; 8	4; 5; 8	14; 22; 32	/	/
	Main mode travel time (hour:minute)						
300-400 km		2:40; 3:20; 4:00	2:36; 3:10; 5:57	4:22; 5:00; 5:50	1:11; 1.25; 1:46	1:05; 1:12; 1:19	1:05; 1:12; 1:19
400-500 km		3:21; 4:11; 5:02	2:55; 3:33; 6:39	5:37; 6:25; 7:30	1:26; 1:43; 2:09	1:17; 1:25; 1:34	1:17; 1:25; 1:34
500-600 km		4:02; 5:02; 6:03	3:12; 3:55; 7:17	6:52; 7:51; 9:10	1:40; 2:00; 2:30	1:29; 1:39; 1:48	1:29; 1:39; 1:48
600-700 km		4:43; 5:54; 7:05	3:28; 4:16; 7:54	8:07; 9:17; 10:50	1:49; 2:11; 2:43	1:41; 1:52; 2:03	1:41; 1:52; 2:03
700-800 km		5:25; 6:46; 8:07	3:43; 4:34; 8:28	9:22; 10:42; 12:30	1:51; 2:14; 2:47	1:53; 2:05; 2:18	1:53; 2:05; 2:18
800-950 km		6:17; 7:51; 9:25	3:54; 4:47; 8:52	10:56; 12:30; 14:35	1:59; 2:23; 2:59	2:07; 2:22; 2:36	2:07; 2:22; 2:36
	Buffer time for air modes (hour:minute)	/	/	/	1:45	1:00	1:00
	Main mode cost (EUR)						
300-400 km		105; 140; 175	27; 57; 92	13; 23; 37	76; 189; 302	123; 210; 420	123; 210; 420
400-500 km		135; 180; 225	34; 70; 112	17; 29; 48	81; 203; 324	144; 257; 504	144; 257; 504
500-600 km		165; 220; 275	39; 81; 131	21; 36; 58	90; 226; 361	160; 297; 572	160; 297; 572
600-700 km		195; 260; 325	45; 92; 148	24; 42; 67	94; 234; 374	169; 332; 624	169; 332; 624
700-800 km		225; 300; 375	50; 103; 165	28; 48; 77	96; 240; 384	173; 360; 660	173; 360; 660
800-950 km		263; 350; 438	56; 115; 185	32; 55; 89	98; 245; 392	175; 394; 700	175; 394; 700
	Total CO_2-eq emissions per passenger (kg) Access and egress by car/taxi						
300-400 km		27; 34; 41	/	/	114; 128; 142	59; 64; 70	16;21;26
400-500 km		35; 44; 53			144; 162; 180	74; 81; 89	19; 25; 31
500-600 km		43; 54; 65			174; 196; 218	89; 98; 107	22; 30; 37
600-700 km		51; 64; 76			204; 230; 256	104; 115; 125	25; 34; 43
700-800 km		59; 74; 88			234; 264; 294	119; 131; 144	28; 38; 48
800-950 km		69; 86; 103			272; 307; 342	138; 152; 167	32; 44; 55
	Total CO_2-eq emissions per passenger (kg) Access and egress by PT						
300-400 km		/	8; 16; 24	4; 5; 7	107; 121; 135	/	/
400-500 km			10; 20; 30	5; 7; 9	137; 155; 173		
500-600 km			12; 25; 37	6; 8; 11	167; 189; 211		
600-700 km			15; 29; 44	7; 10; 13	197; 223; 249		
700-800 km			17; 34; 50	8; 11; 15	227; 257; 287		
800-950 km			20; 39; 59	9; 13; 18	264; 299; 334		
	Total CO_2-eq emissions per passenger (kg) Access and egress by ride sharing						
300-400 km		/	/	/	/	56; 61; 67	13; 18; 23
400-500 km						71; 78; 86	16; 22; 28
500-600 km						86; 95; 104	19; 27; 34
600-700 km						101; 112; 122	22; 31; 40
700-800 km						116; 128; 141	25; 35; 45
800-950 km						135; 149; 164	29; 41; 52

Note: PT = public transportation (such as U-bahn and bus); Conv. 19-seater = conventional 19-seater; total travel time was calculated as the sum of access and egress time (first- and last-mile time), main mode travel time, and buffer time (for air modes); total travel cost was calculated as the sum of access and egress cost (first- and last-mile cost) and main mode travel cost.

TAB Appendix 2. Attribute levels of SP experiment - business

Distance	Attribute	Car	Rail	Bus	Air	Conv. 19-seater	HEA 19-seater
	Access & egress mode	/	car;taxi;PT	car;taxi;PT	car;taxi; PT	car;taxi; ride-sharing	car;taxi; ride-sharing
	Access & egress time (minute)						
	by car/taxi/ride sharing	/	10; 20; 30	10; 20; 30	53; 88; 123	40; 66; 93	40; 66; 93
	by PT		20; 30; 40	20; 30; 40	140; 175; 245	/	/
	Access & egress cost (EUR)						
	by car	/	6; 8; 10	6; 8; 10	28; 38; 47	18; 24; 30	18; 24; 30
	by taxi		21; 32; 58	21; 32; 58	97; 149; 273	63; 96; 176	63; 96; 176
	by ride sharing		/	/	/	4; 8; 12	4; 8; 12
	by PT		4; 5; 8	4; 5; 8	14; 22; 32	/	/
	Main mode travel time (hour:minute)						
300-400 km		2:40; 3:20; 4:00	2:36; 3:10; 5:57	4:22; 5:00; 5:50	1:11; 1.25; 1:46	1:05; 1:12; 1:19	1:05; 1:12; 1:19
400-500 km		3:21; 4:11; 5:02	2:55; 3:33; 6:39	5:37; 6:25; 7:30	1:26; 1:43; 2:09	1:17; 1:25; 1:34	1:17; 1:25; 1:34
500-600 km		4:02; 5:02; 6:03	3:12; 3:55; 7:17	6:52; 7:51; 9:10	1:40; 2:00; 2:30	1:29; 1:39; 1:48	1:29; 1:39; 1:48
600-700 km		4:43; 5:54; 7:05	3:28; 4:16; 7:54	8:07; 9:17; 10:50	1:49; 2:11; 2:43	1:41; 1:52; 2:03	1:41; 1:52; 2:03
700-800 km		5:25; 6:46; 8:07	3:43; 4:34; 8:28	9:22; 10:42; 12:30	1:51; 2:14; 2:47	1:53; 2:05; 2:18	1:53; 2:05; 2:18
800-950 km		6:17; 7:51; 9:25	3:54; 4:47; 8:52	10:56; 12:30; 14:35	1:59; 2:23; 2:59	2:07; 2:22; 2:36	2:07; 2:22; 2:36
	Buffer time for air modes (hour:minute)	/	/	/	1:45	1:00	1:00
	Main mode cost (EUR)						
300-400 km		105; 140; 175	27; 57; 92	13; 23; 37	76; 189; 302	123; 210; 420	123; 210; 420
400-500 km		135; 180; 225	34; 70; 112	17; 29; 48	81; 203; 324	144; 257; 504	144; 257; 504
500-600 km		165; 220; 275	39; 81; 131	21; 36; 58	90; 226; 361	160; 297; 572	160; 297; 572
600-700 km		195; 260; 325	45; 92; 148	24; 42; 67	94; 234; 374	169; 332; 624	169; 332; 624
700-800 km		225; 300; 375	50; 103; 165	28; 48; 77	96; 240; 384	173; 360; 660	173; 360; 660
800-950 km		263; 350; 438	56; 115; 185	32; 55; 89	98; 245; 392	175; 394; 700	175; 394; 700
	Total CO_2-eq emissions per passenger (kg) Access and egress by car/taxi						
300-400 km		27; 34; 41	12; 20; 27	7; 9; 11	114; 128; 142	59; 64; 70	16;21;26
400-500 km		35; 44; 53	14; 24; 34	8; 11; 13	144; 162; 180	74; 81; 89	19; 25; 31
500-600 km		43; 54; 65	16; 29; 41	9; 12; 15	174; 196; 218	89; 98; 107	22; 30; 37
600-700 km		51; 64; 76	19; 33; 47	10; 14; 17	204; 230; 256	104; 115; 125	25; 34; 43
700-800 km		59; 74; 88	21; 37; 54	11; 15; 19	234; 264; 294	119; 131; 144	28; 38; 48
800-950 km		69; 86; 103	24; 43; 63	13; 17; 21	272; 307; 342	138; 152; 167	32; 44; 55
	Total CO_2-eq emissions per passenger (kg) Access and egress by PT						
300-400 km		/	8; 16; 24	4; 5; 7	107; 121; 135	/	/
400-500 km			10; 20; 30	5; 7; 9	137; 155; 173		
500-600 km			12; 25; 37	6; 8; 11	167; 189; 211		
600-700 km			15; 29; 44	7; 10; 13	197; 223; 249		
700-800 km			17; 34; 50	8; 11; 15	227; 257; 287		
800-950 km			20; 39; 59	9; 13; 18	264; 299; 334		
	Total CO_2-eq emissions per passenger (kg) Access and egress by ride sharing						
300-400 km		/	/	/	/	56; 61; 67	13; 18; 23
400-500 km						71; 78; 86	16; 22; 28
500-600 km						86; 95; 104	19; 27; 34
600-700 km						101; 112; 122	22; 31; 40
700-800 km						116; 128; 141	25; 35; 45
800-950 km						135; 149; 164	29; 41; 52

Note: PT = public transportation (such as U-bahn and bus); Conv. 19-seater = conventional 19-seater; total travel time was calculated as the sum of access and egress time (first- and last-mile time), main mode travel time, and buffer time (for air modes); total travel cost was calculated as the sum of access and egress cost (first- and last-mile cost) and main mode travel cost.

TAB Appendix 3. Survey items regarding attitudes of private travelers

Survey items	Options	Frequency (%)	Mean (Std. Dev.)
Attitude towards new mobility technology			
Among my friends and acquaintances, I am usually the first to use new mobility products.		25/22/22/19/11/1	2.71 (1.36)
I try out new mobility products without hesitation once they are proven to be reliable.		12/16/20/29/22/1	3.34 (1.33)
I try out new mobility products even though I am NOT completely familiar with them.		17/22/22/26/12/1	2.99 (1.33)
Attitude towards environmental policies	1 (strongly disagree)		
Protests to fight climate change are worth supporting	to 5 (strongly agree),	18/13/21/23/23/2	3.25 (1.45)
Greenhouse gas neutrality should be achieved by 2045.	6 (I don't know)	7/8/21/25/36/4	3.87 (1.27)
Below a certain energy cost level (e.g. 25ct/kWh electricity and 1.8 EUR/l gasoline), CO2 tax should be increased to incentivize energy saving.		27/15/21/19/15/4	2.93 (1.54)
Cars with combustion engines should be banned by 2035.		33/17/16/14/19/2	2.75 (1.57)
The conversion of the electricity supply to 100% renewable energy should be achieved by 2050.		10/9/16/23/39/3	3.83 (1.38)

TAB Appendix 4. Survey items regarding attitudes of business travelers

Survey items	Options	Frequency (%)	Mean (Std. Dev.)
Attitude towards environmental policies			
Protests to fight climate change are worth supporting		23/13/19/22/21/3	3.11 (1.52)
Greenhouse gas neutrality should be achieved by 2045.	1 (strongly disagree)	9/8/19/23/38/3	3.84 (1.34)
Below a certain energy cost level (e.g. 25ct/kWh electricity and 1.8 EUR/l gasoline), CO2 tax should be increased to incentivize energy saving.	to 5 (strongly agree),	21/15/23/19/19/4	3.11 (1.5)
Cars with combustion engines should be banned by 2035.	6 (I don't know)	27/15/16/16/23/3	3.03 (1.6)
The conversion of the electricity supply to 100% renewable energy should be achieved by 2050.		10/8/17/21/40/3	3.8 (1.39)
Implemented travel policies in the company/organization			
Financial incentives to use the train		73/27	
Campaigns to raise awareness of sustainable travel behavior		81/19	
Binding, limited choice of mode of transportation		81/19	
Recommendations for choice of transport mode		63/37	
Option of CO2 compensation (or purchase of sustainable aviation fuels (SAF))		89/11	
Mandatory CO2 compensation (or purchase of sustainable aviation fuels (SAF))	0 (not implemented) /	95/5	/
CO2 budget (e.g., their organization measures and limits allowable GHG emissions from business travel per person/year)	1 (implemented)	92/8	
Measures to provide non-financial rewards for sustainable behavior		92/8	
Employer commitment to reduce greenhouse gas emissions (e.g., SBTI, RE100, or similar).		92/8	
Others		99/1	
None of the above		71/29	
Acceptance of sustainable business travel measures			
Internal awareness campaigns to reduce business air travel		64/36	
The organization highlights individuals or groups that significantly reduce their personal business travel emissions, fly little, or demonstrate special efforts to achieve this goal.		80/20	
The organization recommends the use of rail to destinations that can be reached by train within 4 hours	0 (not accepted) /	48/52	/
The organization measures and limits the permitted greenhouse gas emissions from business trips per person/per year (CO2 budget) and thus indirectly limits the amount of business air travel	1 (accepted)	80/20	
Mandatory use of rail to destinations that can be reached within 4h by train		62/38	
Mandatory use of rail to destinations that can be reached within 8h by train		84/16	
None of the above		80/20	
Commitment to sustainable business travel	1 (I do not see any reason for that)		
To what extent do you feel committed to make a change to your former business travel behaviour in order to travel more sustainable?	to 5 (I feel strongly commited)	12/16/25/35/13	3.2 (1.2)