The Role of 'Fully Electric Aircraft' for Sustainable Aviation

Analysing the opinions of potential customers towards fully electric aircraft

Master Economic Geography

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Abstract

The aviation industry like many other sectors is grappling with the challenges of moving towards a more sustainable way of operating. At the same time smaller regional airports are often underutilised and missing out on flights to larger airports. One of the proposed solutions currently in development is that of fully electric aircraft. These aircraft would (initially) fly shorter distances than conventional aircraft and so have the potential to connect smaller airports which are currently not well served and as such offer few economic benefits to their surrounding areas. Potential customers views are evaluated to see whether they would intend to travel with such aircraft if and when they come into service. The theory of planned behaviour is used to analyse the factors behind these intentions along with questions about previous travel behaviour. The majority of respondents would indeed intend to use such aircraft and so this raises the prospect of fully electric aircraft connecting smaller cities going forward.

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Chapter 1 –Introduction

Aviation contributes annually to roughly 1.9% of all greenhouse gas emissions (Ritchie & Roser, 2020), with that figure set to rise, mainly as a consequence of more people flying, in the period from 2000 to 2050 by a factor of between 2.0 and 3.6 depending on the success of mitigating measures taken by the industry (Owen et al., 2010). Most of these emissions, approximately 81%, come from passenger travel of which 60% is long haul and 40% short haul (ICAO, 2019). Passenger air travel therefore contributes to a sizeable amount of total emissions and, as a result, must be reduced if global climate change targets, such as the Paris climate agreement are to be met (Larsson et al., 2019).

At the same time, international connectivity for regions is important in an ever-globalising economy, with those regions that are more connected benefitting from long-run regional income and higher levels of productivity (McCann & Acs, 2009). Airports are important in providing such international connectivity, though there are large discrepancies between large and smaller airports with large airports up to 3.5 times better connected than smaller airports (Antunes et al., 2020). At the same time, secondary airports have latterly seen their flight numbers diminish as low-cost carriers move their operations to primary airports and away from those secondary airports which were predominantly where they had based themselves (Jimenez & Suau-Sanchez, 2020). Mukkala and Tervo (2013) investigate the causality between air transportation and regional growth and find air transport can indeed bring regional growth and is especially evident for peripheral regions that may not be so well connected via road or rail, though these are usually very small towns with very small airports. However, smaller airports that are often closer to small or medium sized regions contribute little to regional accessibility and thus due to their small size are ineffective in generating economic growth for the region (Pot & Koster, 2022). Therefore, for secondary smaller sized airports a solution must be found in order to bring about improved connectivity and economic growth from their operations whilst operating as sustainably as possible to compete with other more sustainable transport options. Larger airports may at present be more efficient in providing connectivity to multiple destinations but airport surfaces contribute to large levels of emissions (Miyoshi & Mason, 2013) and access is coupled with longer journeys from the origin city and as such are less sustainable, due to the fact that currently many passengers already have a sizeable journey by car or public transport in order to reach airports offering cheaper flights, creating additional emissions than if they were to travel from their nearest airport. However, more aircraft movements at smaller airports would also come with considerable sustainability and environmental problems and are thus often not approved by local policy makers. Currently therefore, whilst regional airports are not yet fulfilling their full potential regarding providing connectivity as a base for regional growth in peripheral regions, increasing the number of flights would be inefficient and unsustainable.

One potential solution is that termed 'Fully Electric Aircraft' (FEA) which would aim to make the airline industry's flying activities emission free through the introduction of new smaller electric aircraft (initially with a shorter range), which thus emit far fewer emissions than current short-haul aircraft (Sharmina et al., 2021). At the same time, the tickets for these flights will aim to be competitively priced against the current short-haul airlines thanks to lower fuel and maintenance costs (Hospodka et al., 2020). This would enable airlines to operate more direct flights between smaller regional airports, than is currently the case, whilst offering competitive prices compared to airlines operating from larger airports. FEA may bring about a reversal in the trend of airlines moving from secondary to primary hubs as smaller aircraft will be able to connect smaller airports that are unviable with current aircraft. These routes would thus compete with current routes offered by airlines as well as potentially competing with other forms of transport such as train, car and long-range busses, whilst at the same time being equally or more sustainable than these options. Fully Electric Aircraft therefore have the potential to connect these secondary airports to other regions and may enhance the economic growth of a region, something that would be of interest to policymakers.

However, it is uncertain whether FEA will be able to compete with current transport alternatives or if customers would rather stick to those travel arrangements and modes already available. It is therefore important to gauge the potential demand for such an alternative to see if it is worth pursuing and to understand which factors are most important for potential customers when considering whether they would use FEA or other alternatives. FEA can increase connectivity for smaller secondary airports and give passengers and alternative on these routes other than car and rail or first commuting to a primary airport further away. However, it may be that there is in fact little appetite from customers to fly from these secondary airports and they would prefer the services offered by primary airports, making it difficult for FEA to counter this trend. Studies have shown that some travellers are willing to travel further by car or train to reach airports with more facilities and better serviced routes (Lian & Rønnevik, 2011). This, however, may turn out to be less of an issue if passengers see the advantage of taking a more sustainable aircraft from an airport closer by and may at the same time give competition to rail and car routes. Factors such as the availability of direct flights (Berry & Jia, 2010), convenience and the service provided (Adler et al., 2005) may influence the decision-making of consumers when deciding which travel mode to choose and whether FEA could be a viable alternative. Also, it may be the case that the attitudes of passengers towards the environment influences their travel decisions (Kahn & Morris, 2009). Furthermore, it may be that flying has a bad reputation and so automatically gives the environmentally conscious a preference for taking alternative modes of transport. FEA may have the potential to make new routes commercially viable, possibly leading to a revival of secondary airports and countering the flow towards larger primary airports, but this may hinge on whether regional airports can improve their connectivity to city centres and turn the tide of the trend towards flying to larger hubs that has been gaining momentum in the last few decades.

Therefore, a solution which brings competitively priced, sustainable air travel closer to the consumers' starting and end points would reduce not only the emissions from the flight itself but at the same time reduce emissions from initial and onward travel, would potentially have a positive impact on emissions reductions and increase usage of smaller airports.

To test whether FEA have the potential to bring about change in the airline industry, customer intentions will be measured using a survey, and analysed using the theory of planned behaviour, in the city of Groningen, currently home to a secondary airport which serves mainly summer routes to popular holiday destinations (Lieshout, 2012) but is under pressure from other airports in the Netherlands, namely Schiphol and Eindhoven, with Schiphol particularly having a strong hold on passengers travelling to and from the city. Potential FEA routes may link the city with the likes of Hamburg, Frankfurt, Brussels and Paris which would directly compete with alternatives such as inter-city bus, car and train. Groningen is therefore ideally placed to compare people's attitudes to various transport modes for the short distances proposed for FEA.

Research objectives

The introduction of FEA may have large ramifications for regional airports as these become better utilised and in a sustainable way as a result of the new technology. The introduction of FEA has the potential to bring with it large changes to the airline industry and give a real sustainable alternative for taking flights with traditional aircraft or driving over long distances. However, since the technology does not currently exist it is important to gauge public opinion about their willingness to use such a service and whether this would be preferable to the options that are currently available such as trains and cars. The aim of this research is therefore to evaluate the intention to use FEA, specifically departing from a regional airport where the benefits may be the most profound, and compare this with their views towards transport options that are currently available and see which would be preferred in certain circumstances.
The research question is therefore 'To what extent are potential passengers willing to use Fully Electric Aircraft compared to transport options that are currently available?'.
With the following sub-questions:

- Do all the factors in the theory of planned behaviour (Attitudes, Price sensitivity, Subjective Norms, Perceived behavioural control) along with environmental views influence the intention to take FEA?

- To what extent do previous travel modes influence the intention to take FEA?

- How does the willingness to use FEA compare to other modes for the same destination?

Societal relevance

To reach the emissions targets, set out in the Paris Climate Agreement among other international treaties it is essential that polluting industries do their part in reducing the amount of CO2 they produce. Air travel is an industry with particularly high levels of emissions per passenger (Prussi & Lonza, 2018) and so if these targets are to be met, greener alternatives will have to be implemented. Some of the problems associated with air traffic at a local level should be alleviated with the introduction of FEA, as these aircraft will be much quieter and will also require shorter runways than current aircraft types which may lead to less resistance from local residents for investments in airports. This may also help airports to increase aircraft movements which are currently regulated within the EU by strict directives controlling for noise pollution (Gualandi & Mantecchini, 2008).
Whether FEA can be part of the solution needs to be tested through ensuring that there would be a willingness of passengers to travel with these new aircraft types and an emphasis on smaller airports than are currently utilised by airlines. If there is ample demand for these new solutions it may see new air routes and due to the smaller numbers of seats available on these routes, it should make it possible to connect smaller cities to each other whilst remaining commercially viable (Holmes et al., 2004), something which may not have always been possible for low-cost carriers, hence why they have moved in and out of many regional airports when they were no longer profitable. The benefits of connectivity by air have been studied by Smyth et al. (2012) who have shown that the wider economic benefit of increased air connectivity in Scotland is positive, through increasing both business and personal travel to the regions. The development of FEA could lead to the reversal of the move towards bigger airports in larger cities and as a result could lead to a shift in the airline industry and bring about change to how it operates. FEA have the potential to give regional airports a sustainable and economically viable network thus increasing regional connectivity.

By gauging how popular FEA may turn out to be, plans can be set out by regional governments to prepare for and ensure that these regional airports are sufficiently connected in order to make them as attractive as possible. However, if it turns out that potential passengers would rather take the likes of train service or the (fully electric) car to their destinations then investments can be prioritised for those instead. It is important for local planners to be able to gauge the kind of transport modes that will be popular in the future to ensure that they fit within the complete transport options of a region. This research can then be used to further strengthen the connectivity options of Groningen and other similar sized cities and may as a result have economic benefits for the region as a whole.

The public relevance of this thesis is to determine the willingness of society to use FEA in the future and whether this is more or less popular than current transport options. This is useful for policy makers as they can anticipate what transport connections may look like between mid-sized European cities in the future. It is also important to determine how important consideration of the environment is when making these travel choices and whether or not the public are willing to engage with new sustainable options as they become more prolific or whether price and convenience will be more important for future travellers who look to maintaining the use of current transport options they have become accustomed to.

Scientific relevance

The scientific relevance of the research is that it contributes to research on individuals' perceptions of various transport modes, in this case specifically what they think about FEA as a concept and at the same time includes participants' environmental perceptions and whether this is an important factor when deciding which transport mode to choose from. Previous studies have investigated the relationship between time and cost for transport decisions, but whether this is just as relevant when taking sustainability choices into account should also be investigated. At the same time passengers may be weary of new transport options due to fear of the unknown or safety concerns which makes studying the willingness to use new transport options important for research into other potential new transport modes going forward. The research will add to the broader knowledge on including subjective elements to travel mode choice behaviour, previous studies have looked at additional factors to participants' psychological traits (such as attitudes) by considering factors such as the importance of comfort and safety for students' travel mode decisions (Cattaneo et al., 2018). Other studies have also assessed the importance of cultural attributes in influencing travel choices (Le Loo et al., 2015) as well as the effect of environmental consciousness on transport choice behaviour (Shen et al., 2008). Considering potential passengers' environmental views whilst considering a new type of transport is also an important addition to current research as reaching environmental goals requires participation among the widest possible members of society if they are to be met (Patchen, 2006).

Thesis layout

In the following sections a description of Fully Electric Aircraft will be given, followed by a discussion of the theoretical framework that will be used in the study. Thereafter an explanation of the methodology used to create, conduct and analyse the survey will be given. The survey results will then be presented and discussed before a conclusion is given regarding the potential customer appetite for new FEA services and what questions still remain unanswered for the potential future of FEA.

Chapter 2 – What are Fully Electric Aircraft?

The aviation industry is currently exploring various ways to reduce the amount of emissions produced through their flight operations. To do so, a combination of approaches will have to be employed (Owen et al., 2010). Solutions may be found in alternative fuel types for existing aircraft such as bio-fuels (Hari et al., 2015) ; Reducing the number of engines an aircraft is fitted with ; and using smaller aircraft types to fly direct routes are also becoming ever more popular among airlines as they try to reduce the total emissions they emit from their fleets and attempt to by-pass large airport hubs in favour of flying directly to their destinations (Gillen, 2005).

One alternative is that of replacing aircraft systems that currently rely on other propulsion systems with electric alternatives, known as 'more electrical aircraft', thereby increasing efficiency, and reducing emissions, without compromising on aircraft size and not totally redesigning currently operated aircraft (Sarlioglu & Morris, 2015). This however does have the disadvantage of continuing to rely on fossil fuels for the main component of propulsion.

Several companies are currently attempting to build fully electric aircraft as the switch from fossil fuels to sustainable energy sources becomes increasingly important for future transport options, as has happened in the past few years with the move to electric vehicles, where countries now aim to stop the sales of non-electric driven vehicles in the coming decades (Burch & Gilchrist, 2018). Fully electric aircraft would be the move towards an aircraft that is fully electric and powered preferably by renewable energy sources. These aircraft currently in development will initially have capacity for between 9 and 19 passengers and as the battery technology improves aims for increasingly larger aircraft. Though the number of passengers would be much fewer than current short-haul alternatives (with capacity between 100 and 200 passengers) companies will aim to offer tickets that are competitively priced against current airlines.
The technology however is currently in its early stages of development, one company, Pen-Em hope to offer the smaller aircraft from as early as 2023. Other companies such as Heart Aerospace based in Gothenburg, Sweden are also hoping to have an all-electric 19-seater aircraft in service by 2024 (Nowack, 2020).

There are, however, disadvantages with these new fully electric aircraft. Firstly, nearly all of those that are currently in development are far smaller than current short-haul aircraft which makes it difficult for airlines currently operating to replace large numbers of their fleets with such small aircraft whilst maintaining overall seat capacity. At the same time, current batteries that are to be used in such aircraft are very heavy for the amount of power required (Tariq et al., 2016) and unlike burning fuel which makes the aircraft lighter upon landing these aircraft maintain the same weight for both take-off and landing, meaning a much higher payload must be transported throughout the duration of the flight, reducing their range. Thirdly, the production of the required electricity is also an important factor to consider when evaluating whether the aircraft are in fact more environmentally friendly as the electricity production differs greatly between countries (Brodny & Tutak, 2020).

Therefore, there is still a fair way to go before fully electric aircraft can be completely commercialised. The coming years will be crucial in determining whether fully electric aircraft can break through and become part of the solution to the aviation industry's emission reduction targets, the first companies developing such aircraft aim to be a part of this transformation bringing short haul flights to realisation by 2023 with the aim of initially connecting cities to a maximum of 900km apart in 9–19-seater aircraft. This is therefore an ideal moment to gauge public opinion towards such aircraft.

Chapter 3 – Theoretical Framework

The previous chapters have introduced the concept of fully electric aircraft and discussed the relevance for studying potential customer demand for this new transport type. This chapter focusses on the decision-making process behind choosing between various transport forms and whether FEA may be a viable alternative in the future. Firstly, an overview of transport choice behaviour is given along with the decision-making process for air-travel specifically. Thereafter the theory of planned behaviour will be explained along with a review of some previous papers that have looked at other aspects of transportation mode choice.

Transport choice behaviour

Transport choice behaviour has been studied extensively. Socio-demographic factors have an influence on the travel options available to and the preferences of individuals, travel distances also vary with distance travelled for work, influenced by income for example (Shen, 2000). Travel itself can have both a derived demand but also an intrinsic value of the enjoyment of travelling in of itself (Anable. & Gastersleben, 2005). Contextual factors can also influence travel behaviour by constraining or enabling certain travel options such as availability of cycle lanes and bus routes (Bamberg & Rölle, 2003). Many studies of travel behavioural decisions are largely framed by a broad dichotomy of stated preferences and revealed preferences. Stated preference usually involve a choice set of alternatives and ask respondents to rate different options or choose between various alternatives (Hensher et al., 1988). Revealed preferences in contrast involves the observed choices made by travellers and compares possible other network routes that could have been taken by the passengers. Both methods can be used to derive the value of various travel attributes such as price, time and transport type (Lerman & Louviere, 1978). Willingness to use new transport options have been investigated in various studies such as Eker et al. (2020) who look at users' willingness to use flying cars and the paper of Han et al. (2019) who look at the willingness to use environmentally friendly aircraft compared to environmental attitudes. However, these studies do not look at the alternative transport modes that could be chosen over those that were studied. Another study looked at the impact of different factors such as price and weather affect the willingness to travel by autonomous air taxis (Ragbir et al., 2020). Other studies have looked at passenger perceptions of low-cost carriers which were a revolution in air travel at the time (Buaphiban & Truong, 2017) and (Pan & Truong, 2018) and found them to be mostly positive in Asia and the US. Thus, with the implementation of FEA it is important to research potential passenger opinions as it may be that this leads to a similar revolution within the airline industry.

Air travel as a transport mode choice

Travel mode behaviour between different transport modes have been studied extensively, with studies comparing different modes, the importance of time and comparisons across countries. Aviation specifically has been studied compared to other possible transport options. For example, Román et al. (2007) investigate the competition between train and air travel between Barcelona and Madrid and find that passengers have a higher willingness to pay for faster air travel than taking the train but may be more favourable for the train for shorter distances. The determinants of long-distance travel have been studied, where location, income and gender can influence the tendency to travel long distances (Dargay & Clark, 2012) and that for the UK coach travel is seen as an inferior form of transport compared to air travel. Distance has also been found to be a determining factor when comparing long distance transport modes where employment status and social status have an impact on the distance travelled by various forms of transport (Scheiner & Holz-Rau, 2007). Automated vehicles have also been studied as a new mode choice compared to air travel, research found that shifts in mode usage vary over different distances with airlines remaining more popular for distances above 500 miles, cost became a less important factor as the perceived benefits of driverless travel were taken into account (LaMondia et al., 2016). Other studies have looked at passenger perceptions of low-cost carriers which were a revolution in air travel at the time (Buaphiban & Truong, 2017) and (Pan & Truong, 2018) and found them to be mostly positive in Asia and the US. Thus, with the dawn of FEA it is important to research potential passenger opinions as it may be that this leads to a similar revolution within the airline industry and various groups' current transport choice preferences may influence their intentions to use such flights in the future.

Fully Electric Aircraft as a new form of transport also needs to be studied to see where it would fit into the current transport mode choices and whether passengers are willing to make use of a new form of transport and how this may impact on train and car usage for similar distances and whether it will contribute to the transport mix of cities in the future, opening new possibilities to connect cities to one another.

Analysis of factors influencing the decision to take Fully Electric Aircraft or not

The theory of planned behaviour is used to investigate consumer decision making and is based on the theory of reasoned action with the addition of the factor perceived behavioural control (Ajzen, 1991). The theory of reasoned action states that behaviour is determined by the intention to perform the action and this intention is made up of "attitudinal" and "normative" factors. The addition of perceived behavioural control allows for the participants' belief that they can perform an action in a specific situation to be accounted for (Ajzen, 1991) Figure 1 shows the original theory of reasoned action with the addition of perceived behavioural control making up the theory of planned behaviour. Price is also included in the model as it has been found to be significant in previous studies when looking at transport mode choice (Ong & Tan, 2010).

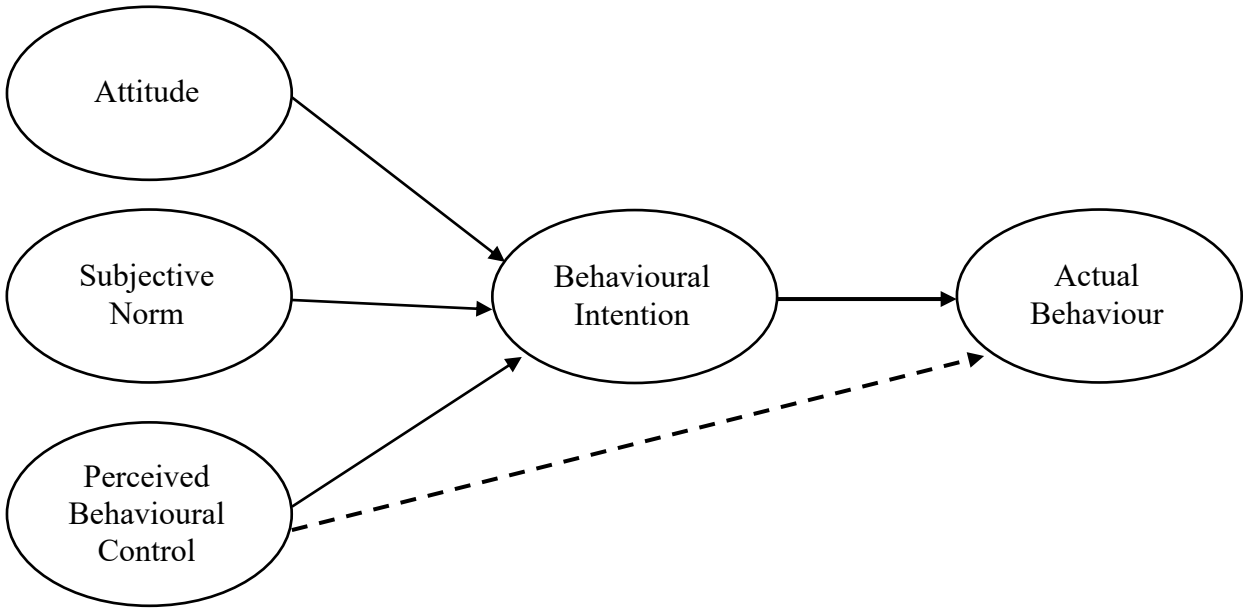

Figure 1 – Theory of Reasoned Action

The theory of planned behaviour will be used to study the potential demand for FEA. Along with price a further addition to the theory of planned behaviour will be used to allow the measurement of environmental views held by the participants, Si et al. (2020) used the model to investigate the usage of bike sharing services and how this was affected by the users' environmental views. This is an important addition to the model as one of the main selling points of FEA are their environmentally neutral credentials and thus may be a more attractive option than for those who are more environmentally conscious. Especially considering the negative views many hold towards air-travel as being environmentally unfriendly (Becken et al., 2022). Additionally, previous travel behaviour is also expected to influence the intention for participants to use FEA or not and is also added to the analysis, with those travelling more frequently by air potentially more likely to choose FEA than those who travel abroad mostly by car or train.

The following 5 factors are all expected to influence the intentions of the participants in the survey, namely whether or not they would be willing to use FEA as a means of transport or whether they would rather choose alternative transport options. The factors are taken from the theory of planned behaviour:

Attitudes

Attitudes concern how the participants regard certain possible actions that can be taken, these attitudes should thus correlate with the actual behaviour a participant would engage in. In the case of FEA, individuals may appraise it in terms of how convenient or pleasant taking FEA would be when compared to other transport options. Kuppam et al. (1999) find that passengers who are more likely to take the bus for their daily commute find it more convenient than other options available to them.

Price

Oum et al. (1992) look at price elasticities for different modes of transport and different types of users, they find that elasticity is greater for air-travel than for car travel and that elasticities are greater for leisure travellers than business travellers. Price and time consideration are competing factors when individuals decide upon transport options, de Donnea (1972) explains that transport decision choice is equivalent to choosing a combination of money and time. The marginal value of the trip can be partially equated to the comfort of the trip, or for business passengers how productive they can be using that time given the transport mode. Thus faster, more expensive transport modes will be chosen if the value of time saved and the additional comfort is at least as high as the additional cost.

Subjective Norms

Subjective norms refer to the perceived social pressure for taking a certain type of transport based on what an individual's close friends and family would choose. The subjective norms of participants have been correlated to intention to take the bus and bus use in Canada, (Liu et al., 2017), illustrating that the perceived perceptions of others within an individual's social circle do have an impact on their transport mode choice decisions. Other studies have found subjective norms to be an important determinant of intentions to perform sustainable behaviour, for example (Si et al., 2020) for the adoption of dock less bike sharing in China, and for the reduction of construction waste production for employees (Li et al., 2018).

Perceived behavioural control

Perceived behavioural control is the degree to which participants feel that they are able to decide for themselves which transport options they would like to take, how easy they find it to book different travel options for instance. Perceived behavioural control is an addition to the theory of reasoned action which additionally studies how much the participant feels they are in control of the actions they can choose (Terry & O'Leary, 1995).

Environmental Views

The environmental views of the participants are expected to influence the willingness to take FEA instead of other potential transport options especially if they vary in terms of environmental impact. In her paper, Jensen (1999), looks at the attitudes towards the environment and found that although there was a large amount of understanding with climate issues, she found that most users' behaviour did not match their environmental ideas, with users still travelling by car for small distances. She was also able to group users based on various socio-demographic descriptors with those more environmentally conscious more likely to cycle for certain types of journeys. Donald et al. (2014) extend the theory of planned behaviour to include environmental views. They found that environmental concern had a positive impact on taking public transport and a negative influence on car usage, showing that it can be a valuable addition to the model when comparing more environmentally friendly transport options to less so alternatives.

All the above factors form the basis for the survey which will evaluate public opinion on FEA and whether or not the participants would be willing to use such electric aircraft if and when they come into commercial service in cities such as Groningen.

Chapter 4 – Methodology

The preceding 3 chapters have presented the research question, a description of what is meant by Fully Electric Aircraft and discussed the theoretical framework to the research. Perceptions towards FEA are evaluated using a survey conducted in Groningen. Groningen is a city located in the north of the Netherlands with a population of around 230,000. Groningen currently has a small airport which mainly operates charter flights during the summer period. Groningen is well placed with train and road connections to Germany and is a 2-hour train ride from Schiphol, the largest airport in the Netherlands. Within the survey various transport modes are compared by the participants and using a modified version of the theory of planned behaviour the willingness to potentially use FEA is examined. The survey results are collated and analysed to understand the most important factors behind whether or not to choose FEA and if not, which transport modes are preferred and under which circumstances.

Survey design

A survey is employed to gauge public opinion about the possibility of using FEA in Groningen. As FEA are currently not in operation revealed preferences is not an option in comparing different transport options so stated preferences is used instead in the form of a survey which aims to test the willingness of participants to use FEA in the future and make comparisons to current transport modes. Hess et al. (2007) use a stated preferences model to investigate customer airline and airport allegiance, using stated preference allows the full list of options faced by the customers to be explored, something that is not possible with revealed preference. Using stated preferences, unchosen options can be considered by the respondents, and in the case of FEA can give insight into a travel option that is not currently in existence. Other studies looking at passengers' choice behaviours have made use of a survey to gather public opinions (Pan & Truong, 2018; Buaphiban & Truong, 2017).

The first part of the survey includes an explanation of the purpose of the survey followed by a short description of what FEA are and how they may be implemented in Groningen (For full survey see Appendix). Following the introduction, questions are presented on the 5 factors pertaining to the theory of planned behaviour regarding the potential use of FEA with the addition of environmental views, as mentioned in Chapter 3. The independent variables are taken in turn with questions relating to attitudes, price sensitivity, subjective norms, perceived behavioural control and environmental views. Multiple statements are presented for each factor, each using a Likert scale from 'Strongly Disagree' to 'Strongly Agree' with the possibility to choose 'Not Sure'. Participants are then asked about their intention to take FEA. Thereby fulfilling the required factors for the theory of planned behaviour to analyse the potential willingness to use FEA.

Additionally, different scenarios are presented where potential journeys that could be made with FEA are compared with taking the train or travelling by car, here the variable of interest is which transport mode the participants would favour in each scenario. Different journey times and prices are given in order to gain an insight into what participants find important when making travel choices. Finally, demographic questions are presented. A table showing an overview of the independent, dependent and control variables is given in Table 1. The questions for the intentions and scenarios are presented in Table 2 and the factor scores behind the independent variables in the theory of planned behaviour is given in Table 3.

Table 1 – Overview of independent, dependent and control variables

Variable	Type	Variable	Type
Attitudes	Independent (TPB)	**Salary**	Control
Price sensitivity	Independent (TPB)	**Education**	Control
Social norms	Independent (TPB)	**Employment status**	Control
Perceived behavioural control	Independent (TPB)	**Age**	Control
Environmental views	Independent (TPB)		
Train usage previous year	Independent		
Plane usage previous year	Independent		
Car usage previous year	Independent		
Intentions	Dependent		

Table 2 – Survey questions for intention to take FEA and 4 scenarios

Intentions/ Scenarios (For scenarios the statements are I would rather take FEA than the car, I would rather take the train than the car and I would rather take FEA than the train)	I would consider taking FEA Imagine travelling from Groningen to Hamburg (roughly 200km) the prices are FEA €60, Train €50 and car €55. Imagine travelling from Groningen to Frankfurt (roughly 400km) the prices are FEA €100, Train €90 and car €70. Imagine travelling from Groningen to Hamburg (roughly 200km) the travel times are FEA 2 hours, Train 2 hours and Car 2.5 hours. Imagine travelling from Groningen to Frankfurt (roughly 400km) the travel times are FEA 2.5 hours, Train 3.5 hours and Car 5.5 hours.

Data collection

The survey was created using Qualtrics and was completed online by the respondents. The survey was distributed in Groningen and completed by inhabitants of the northern provinces of the Netherlands. Non-probability sampling was used, namely convenience sampling due to time constraints. Participants were approached in person and given a QR code in order to fill in the survey in various central locations in Groningen and survey links were also shared on social media. In total there were 97 respondents to the survey. As a result of using a non-probability sampling technique the data may not be truly representative of the population of Groningen as a whole as it may be the case that only a certain type of respondent fills in the survey, for example those who are more environmentally conscious or students who have more time to do so. It may also be the case that only a certain subset is reached through the means available, for example younger people who can more easily access the survey online. However, the demographics of the respondents can be compared with the demographics of the population as a whole to check that the subset is representative of the whole across certain dimensions, the populations of the survey and the actual population of Groningen do not differ severely in this case (see Chapter 5 descriptive results).

Analysis

The theory of planned behaviour posits that several factors will have an impact on the intentions for an individual to perform a certain behaviour. For the case of the intentions to use FEA this is assumed to be related to the factors listed previously in Chapter 3. Also, the interaction between the factors and previous years' chosen transport means may or may not influence the decision to take FEA.

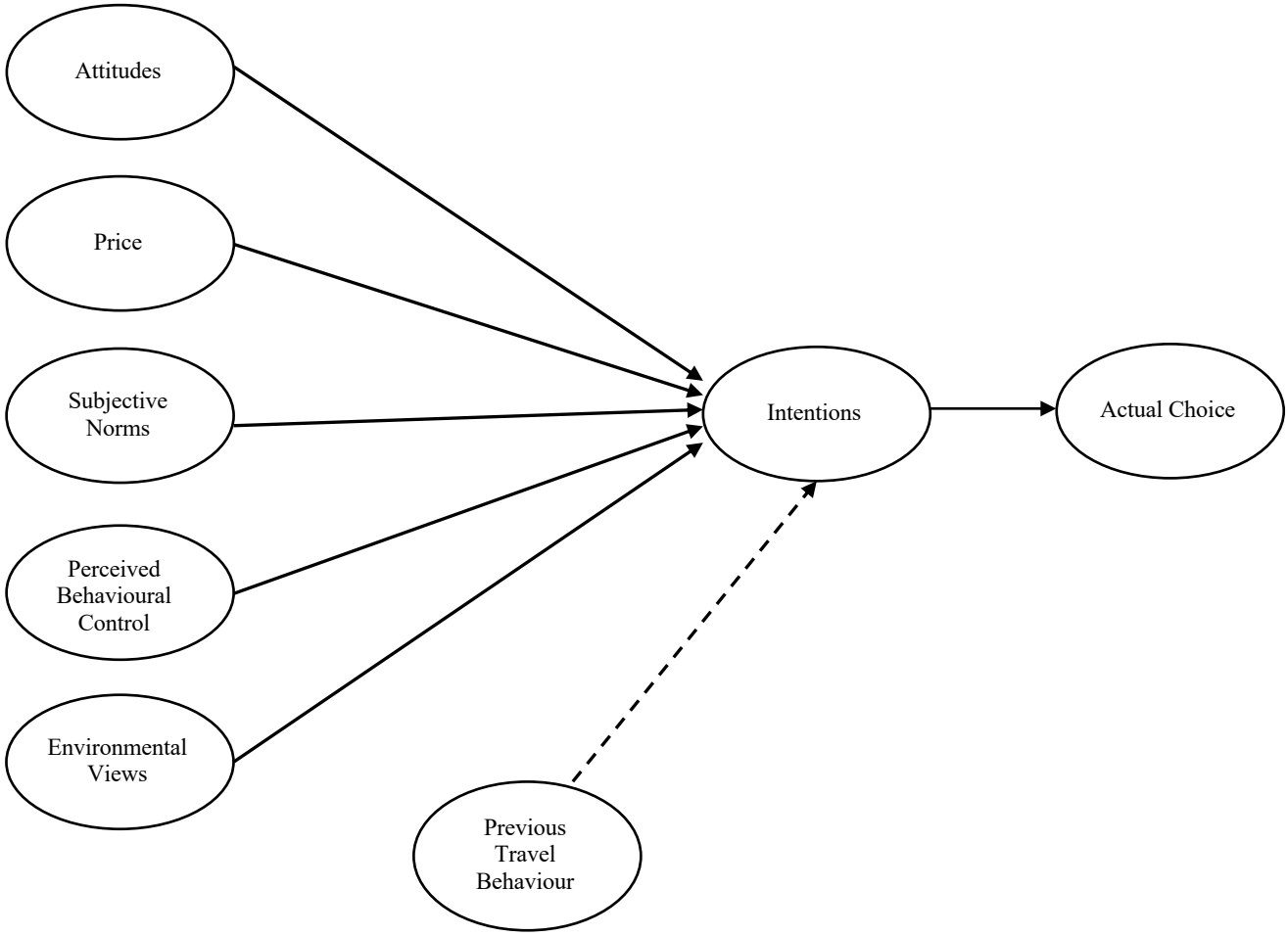

Figure 2: Conceptual Model

The effect of various factors on the intention to take FEA are analysed using a two-step approach for data analysis (Hair et al., 2013). Firstly, confirmatory factor analysis is used to ensure that the combined measures for the various factors reliably and validly represent the constructs. An important assumption of the study is that these interact as distinct constructs and thus needs to be confirmed empirically. Secondly, multiple linear regression analysis will be used with the intention to use FEA as the dependent variable and the aforementioned factors as the independent variables, regression analysis is used to analyse if there are any significant relationships between the factors and the intention to use FEA. A block wise regression is used where factors for the TPB are added to the control variables and also to a separate model in order to examine relative influences between the models.

For the analysis of the theory of planned behaviour often structural equation modelling is used, however this requires larger sample sizes, for a sample size of 100, SEM has an insufficient power to be able to confidently carry out hypothesis testing (MacCallum et al., 1996). Though the sample size required for the number of factors used in the survey was not attainable in the time period available for conducting the research.

To determine whether potential users would travel by FEA the survey gives the participants the opportunity to choose between various transport options. Researchers would usually use a discrete choice experiment but this was out of scope of this research as it would require too many additional questions on top of the TPB and would have been difficult to include in the survey, so a few questions were posed in order to ascertain preference of the participants though it was not a fully-fledged discrete choice experiment.

Factor analysis was performed on the statements making up each of the 5 independent variables for the analysis. The responses 'don't know' were recoded to missings to perform the factor analysis. Various assumptions are made to perform the analysis, firstly the data is checked for outliers and each of the variables in the factors are checked for multicollinearity, these all conformed to the assumptions and so the analysis could be performed. The factor analysis grouped the various statements into the 5 latent factors. The fit of the factor analysis, using principal component factors, is determined using the Eigen values from the various factor models, with an Eigen value above 1 showing a good fit of the factor analysis, according to the Kaiser Criterion (Yeomans & Golder, 1982). This process was repeated for all 5 of the independent variables. These factors are taken as sufficient representations of the various elements making up the model of planned behaviour. These factors are then used in the regression analysis to confirm or dispose of the hypotheses regarding the intention to use FEA or not. The factor analysis results are presented in Table 3 below.

Table 3 – Factor Analysis

Construct	Item	Factor Loading	Cronbach's alpha	Eigen value
Environmental views			0.8080	1.6076
	I try to make environmentally conscious decisions	0.7331		
	The environment is very important to me	0.7381		
	The government should invest more in sustainable transport	0.7249		
Price sensitivity			0.9097	2.1697
	I would pay more for environmentally neutral transport	0.8088		
	I would choose FEA even if it is more expensive than a normal plane ticket	0.897		
	I think sustainability is more important than price	0.8432		
Subjective norms			0.8000	1.5486
	Those close to me would approve of using FEA	0.6840		
	Those whose opinions I value would choose FEA	0.7326		
	My friends would approve of me using FEA as an environmentally sustainable transport option	0.7376		
Perceived behavioural control			0.7902	1.5976
	I have control over which means of transport I choose	0.5731		
	I am able to decide myself whether to take a train/plane or drive	0.7846		
	I have the possibility to decide between different forms of transport	0.8084		
Attitudes			0.7156	1.3911
	I think travelling by FEA would be pleasant	0.6716		
	I would find FEA convenient	0.5444		
	I would find FEA comfortable	0.8022		

Hypotheses

Following on from the analytic strategy hypotheses can be drawn from the expected outcomes of the analysis of the theory of planned behaviour in relation to fully electric aircraft, the 3 hypotheses for the study follow below.

Hypothesis 1: All the factors in the model (environmental views, price, subjective norms, attitudes and perceived behavioural control) will positively influence the intention to use Fully Electric Aircraft.

The construct *environmental views* is expected to positively influence the intentions to use FEA as its main selling point is that it is billed as a fully sustainable form of transport and thus those who place importance on the environment should consider FEA favourably. Previous research has shown that level of concern about the environment is positively related to the intention to use alternative public transport instead of going by car (Gardner & Abraham, 2010).

The *price* construct has been found to be significant for passengers when deciding upon whether or not to use low-cost carriers in China (Pan & Truong, 2018). It is expected that the importance of price will be positively related to the intentions to use FEA and thus will be an important determinant in the planned behaviour of the participants. However, it may be the case that price in fact is less important for determining the intended usage of FEA as potential passengers are happy to pay more in order to travel with a sustainable means of transport (Gaker et al., 2011).

Subjective norms are expected to influence the intentions to use FEA, the opinions of those around them are expected to be a determinant in whether the participants intend to use FEA or not. Eriksson and Forward (2011) find that subjective norms are positively related to the intention to use a car, bus or bike. It is therefore assumed that subjective norms will also be related to the intention to take FEA.

Attitudes are also expected to be positively related to the intention to take FEA or not. It follows that those who think positively about FEA are also more likely to intend to take FEA. In their study Donald et al. (2014) find that attitude has a positive effect on the intentions of participants to use public transport.

Finally, *perceived behavioural control* is predicted to be positively related to the intentions to take FEA, as those who feel they are in a position to be able to book tickets for FEA are more likely to see themselves as having the intention to use it. Zailani et al. (2016) study the predictors for taking public transport to three different types of destination they find that perceived behavioural control is significant in relation to the intention to use public transport to travel to all three of these locations.

Hypothesis 2: The frequency of previous travel behaviour will moderate the link between the factors and the intention to take FEA.

Those who travel a lot already by aeroplane or by car may have lower concern for the environment whilst those who travel predominantly by train may be more concerned about the environment hence their current behaviour. It may also be the transport mode they prefer or are most used to. Thus, the current behaviour of respondents may influence the likelihood to intent to us FEA. At the same time there may be heterogeneity among respondents, based on the means they usually travel abroad with respect to the contributing factors that influence their intention to use FEA. For example, those who fly regularly may score higher on average when assessing the perceived comfort of flying with FEA compared with those who currently make more trips by train or car. Anable, J (2005), studies the perceptions of transport users and find those who are heavily dependent on cars are far less likely to view public transport positively.

Hypothesis 3: FEA will be more popular for longer distances compared to taking the train or car as the advantage of a shorter total travel time increases.

As the potential travel time difference increases between scenarios FEA will become more popular than taking the train or travelling by car. At the same time, depending on the distance to the destination and the travel times involved in reaching the destination in various scenarios the contributing variables for the decision to take fully electric aircraft or alternatives will differ. For example, for a shorter distance concern over the environment may be relatively less of a concern compared to travel time between the various options. The previous year's travel behaviour may also influence the actual decision to take FEA or not, as those who travel more by aeroplane in general may be more convinced of the merits of taking FEA compared to those who fly less, but this influence may differ when looking at the travel times and distances involved for the journey as currently it isn't possible to fly commercially for such small distances.

Chapter 5 – Results

Overview and Demographics

The survey was conducted over several months from July to December 2021 with the majority of participants resident in the province of Groningen or Friesland. In total there were 97 respondents of which 81 completed the survey in its entirety. The average age of the respondents was 28 and all but 6 of the respondents reside in the province of Groningen. Of those interviewed, 47 were students, 27 were employed or self-employed, 5 were retired and the remaining 2 were unemployed. These figures align with the statistics for Groningen city centre as a whole (CBS, 2020). On average each participant takes 2.85 round trips abroad per year either by car, train or aeroplane. The respondents were most likely to report travelling abroad at least once per year by aeroplane, with only 15 respondents that don't make any trips by plane in an average year (non-covid19), compared to 29 who don't travel abroad by car and 32 who tend to not make any trips abroad by train. However, in total more trips abroad are taken by train, followed by car and finally by aeroplane, this may be in part due to Groningen's proximity to Germany, with a number of participants taking very large numbers of round trips per year by car and train (See Table 4 for full results). The majority of the participants were in possession of a Bachelor's or Master's degree.

Table 4 – number of foreign trips made in an average year (non-covid19)

	Train	Plane (FEA)	Car
Average trips	3.47945205	2.46575342	2.63013699
Min	0	0	0
Max	60	30	23
Total	254	180	192

Descriptive results

The majority of respondents, 80% (either agree or strongly agree), would consider using FEA when asked if they intended to use FEA. To gauge public opinion, a survey was conducted in Groningen. The most important figures of the independent variables of the theory of planned behaviour are as follows, of those asked 90% said they believe that the planet is threatened by climate change whilst 95% of respondents believe that the government should invest more in sustainable transport, at the same time however only 80% say they try to make environmentally conscious decisions. Looking at the questions on price, 60% of respondents believe that sustainability is more important than price and 57% would pay more for environmentally neutral transport. For personal control, 78% of respondents say that their friends would approve of them using FEA. And finally for attitudes in terms of comfort respondents expected travelling by car most comfortable with 80% finding it comfortable compared with 69% for the train and 54% for FEA.

A choice scenario was given to respondents to give some insight into which transport choice would be preferred given different prices and times taken and for different distances (Overview in Table 5). A full choice experiment was unfortunately out of the scope of this study though the results do give some insight into how popular FEA may be compared to driving and taking the train to certain destinations. For the scenario Groningen to Hamburg the majority of respondents would rather take FEA, or the train as opposed to travelling by car, even though both these options were more expensive in the scenario. For the scenario Groningen to Frankfurt (double the distance) respondents were more in favour of both the train and FEA with a slight preference for FEA compared to the train. When considering time instead of price the preference for taking the train in the first scenario is greater than when looking at price alone and for the second scenario FEA are the most preferable. This may be due to the greater potential benefits in terms of time saved taking FEA on a longer distance compared to shorter distances where taking the train may be just as quick. For all of the scenarios FEA was rated more favourably compared to taking the car than when comparing taking the train instead of the car, though the difference varies across the scenarios.

Table 5 – Overview of intentions/ scenarios 1-4

Dependent variable / scenario	Percentage of respondents who agree		
I would consider taking FEA	80%		
	FEA > Car	Train > Car	FEA > Train
Imagine travelling from Groningen to Hamburg (roughly 200km) the prices are FEA €60, Train €50 and car €55.	70%	61%	46%
Imagine travelling from Groningen to Frankfurt (roughly 400km) the prices are FEA €100, Train €90 and car €70.	53%	50%	52%
Imagine travelling from Groningen to Hamburg (roughly 200km) the travel times are FEA 2 hours, Train 2 hours and Car 2.5 hours.	70%	65%	45%
Imagine travelling from Groningen to Frankfurt (roughly 400km) the travel times are FEA 2.5 hours, Train 3.5 hours and Car 5.5 hours.	83%	76%	72%

Regression analysis

A regression analysis was performed using the predicted values from the factor analysis. The dependant variable being the intention to use FEA and the independent variables the factors representing the 4 factors in the theory of planned behaviour along with the additional factor for environmental attitudes and previous travel behaviour. Also included in the model are four control variables namely salary, education, employment status and age. Two of the scenarios (3 and 4) are also included in a regression, with the first two scenarios deemed unsuitable as price is already an independent variable in the TPB so focussing on travel times is studied instead.

Looking first at *Hypothesis* 1, block wise regression was used in 3 models, with the control variables, the independent variables and finally the control variables and independent variables combined. In the full model, attitudes and social norms were the only significant independent variables with coefficients of 0.3434 and 0.2505 respectively meaning that both these factors have a positive influence on the intention to take FEA. For the remaining 3 factors in the TPB (environmental view, price sensitivity and subjective norms) their influence on the intention to take FEA were insignificant at the 5 percent significance level. Thus, attitudes and subjective norms do have an impact on the intentions of the participants to take FEA. The hypothesis can thus be partially rejected as not all of the factors proposed in the model significantly influence the intentions to take FEA. The full results are presented in Tables 6-8. Interestingly, of the factors that were insignificant price may have been assumed to have the largest effect on a

customer's willingness to take a certain transport option though in this regard those surveyed were more likely to choose based on sustainability rather than on price alone, this result is in line with that of Rice et al. (2020) who find that participants are more likely to pay more for flights which have lower greenhouse gas emissions. The control variables used in the regression analysis include age, education, income, and occupation. None of which had a significant influence on the intention of the respondents to take FEA whether in the individual or combined model. Education interestingly was the most significant and negatively influenced the intention to take FEA.

Turning to *Hypothesis 2*, which stated that the frequency of various transport options taken in the last year will influence the intention to use FEA. The number of journeys taken in the previous year by train, plane or car did not significantly influence the intention to take FEA in the full model (Table 10). Though for the previous travel choices alone in the model (Table 9) the number of flights taken was significant with a coefficient of 0.0272 showing those who had taken more flights in the previous year were more likely to intend to use FEA. *Hypothesis 2* cannot be fully rejected as the analysis shows that in the smaller model the previous year's air travel does influence the intention to take FEA whilst in the full model all of the previous year's travel modes are insignificant. Results shown in Table 9 and 10.

Finally, *Hypothesis 3* is investigated, the intention to take FEA over the train and car are analysed in 2 different scenarios, the first from Groningen to Hamburg and the second from Groningen to Frankfurt (about twice as far) (The first two scenarios were discounted as they focussed on price and this is also an independent variable within the model so scenarios 3 and 4 were chosen as these focussed on time). The percentage of participants saying they would take FEA from the first to the second scenario does indeed increase, from 70% to 83% when compared to travelling by car and from 45% to 72% compared to the train. Thus, FEA is indeed more popular for a journey covering a longer distance. The relative importance of the dependent variables do indeed differ between the two scenarios, for example although insignificant environmental views have more of a negative influence for the second scenario than the first, showing that those who are more environmentally conscious are less likely to take FEA compared to the train or car. Attitudes (significant in two of the regressions) was also relatively more important for the decision of taking FEA over the car than FEA over the train, which may show that attitudes of FEA also very when compared to different travel modes. The previous travel modes also vary in influence between the two scenarios. Thus, hypothesis 3 cannot be rejected as in the case of this scenario FEA is relatively more popular for travelling over a greater distance.

Tables 6,7 and 8 Regression analysis *Hypothesis 1*

Construct	Coefficient	Std. err.	t
Salary	-0.1612	0.1089	-1.48
Education	-0.1463	0.0793	-1.85
Employment Status	-0.1327	0.0749	-1.77
Age	-0.0004	0.0099	-0.04
Constant	4.9822	0.6133	8.12

Table 6

Construct	Coefficient	Std. err.	t
Attitudes	0.3189	0.0949	3.36
Price sensitivity	0.0021	0.1095	0.02
Social norms	0.2672	0.1022	2.61
Perceived behavioural control	0.0421	0.0847	0.50
Environmental views	0.0835	0.1127	0.74
Constant	3.8378	0.0714	53.72

Table 7

Construct	Coefficient	Std. err.	t
Salary	-0.0268	0.0955	-0.28
Education	-0.1369	0.0711	-1.93
Employment Status	-0.0636	0.066	-0.96
Age	0.0043	0.0086	0.50
Attitudes	0.3434	0.0989	3.47
Price sensitivity	-0.0254	0.1153	-0.22
Social norms	0.2505	0.1104	2.27
Perceived behavioural control	-0.0126	0.0915	-0.14
Environmental views	0.1208	0.1229	0.98
Constant	4.3551	0.5354	8.13

Table 8

Table 9 – Regression analyses *Hypothesis 2* (Intention to take FEA) previous travel modes

Construct	Coefficient	Std. err.	t
Train	0.0127	0.0096	1.33
Plane	0.0272	0.0117	2.32
Car	-0.0221	0.0156	-1.41
Constant	3.7910	0.0947	40.02

Table 10 – Regression analyses *Hypothesis 2* (Intention to take FEA) full model and previous travel modes

Construct	Coefficient	Std. err.	t
Salary	-0.1852	0.0996	-0.19
Education	-0.1191	0.0753	-1.58
Employment Status	-0.0621	0.0673	-0.92
Age	0.0043	0.0089	0.49
Attitudes	0.3058	0.1068	2.86
Price sensitivity	-0.0061	0.1185	-0.05
Social norms	0.2605	0.1127	2.31
Perceived behavioural control	-0.0032	0.0935	-0.03
Environmental views	0.1042	0.1262	0.83
Train	0.0064	0.0089	0.72
Plane	0.0095	0.01127	0.84
Car	-0.0029	0.0153	-0.20
Constant	4.2459	0.5552	7.65

Tables 11 and 12 – *Hypothesis 3* (Scenario 3 and Scenario 4)

Table 11 - Scenario 3

Scenario 1 (Hamburg)	FEA > Car			FEA > Train		
Construct	Coefficient	Std. err.	t	Coefficient	Std. err.	t
Salary	-0.2359	0.1358	-1.74	-0.2882	0.1646	-1.75
Education	-0.0056	0.1027	-0.05	-0.0606	0.1250	-0.48
Employment status	-0.1385	0.0918	-1.51	-0.0930	0.1049	-0.89
Age	0.0068	0.0121	0.56	0.0230	0.0142	1.62
Attitudes	0.4005	0.1456	2.75	0.2482	0.1732	1.43
Price sensitivity	0.1409	0.1617	0.87	0.1464	0.1883	0.78
Social norms	-0.1050	0.1537	-0.68	0.0676	0.1893	0.36
Perceived Control	-0.2261	0.1275	-1.77	-0.3017	0.1517	-1.99
Environmental views	-0.1054	0.1720	-0.61	-0.4965	0.2000	-2.48
Train	0.0132	0.0121	1.09	0.0060	0.0143	0.42
Plane	0.0125	0.0154	0.81	0.0039	0.0181	0.22
Car	-0.0229	0.0209	-1.10	-0.0015	0.0246	-0.06
Constant	4.4943	0.7572	5.94	3.6104	0.8734	4.13

Table 12 - Scenario 4

Scenario 2 (Frankfurt)	FEA > Car			FEA > Train		
Construct	Coefficient	Std. err.	t	Coefficient	Std. err.	t
Salary	-0.0743	0.1042	-0.71	-0.3804	0.1259	-3.02
Education	-0.0420	0.0815	-0.52	-0.2207	0.1015	-2.18
Employment status	-0.0798	0.0700	-1.14	-0.2922	0.0837	-3.49
Age	0.0023	0.0092	0.25	-0.0066	0.0111	-0.59
Attitudes	0.2283	0.1144	2.00	0.1751	0.1347	1.30
Price sensitivity	0.0128	0.1241	0.10	0.0121	0.1464	0.08
Social norms	-0.0236	0.1200	-0.20	-0.0783	0.1537	-0.51
Perceived Control	-0.0137	0.1000	-0.14	-0.1394	0.1186	-1.18
Environmental views	-0.1582	0.1340	-1.18	-0.1841	0.1641	-1.12
Train	0.0176	0.0095	1.84	0.0151	0.0112	1.35
Plane	0.0128	0.0121	1.06	0.0217	0.0142	1.52
Car	-0.0460	0.0164	-2.80	-0.0547	0.0192	-2.84
Constant	4.8114	0.5703	8.44	6.4786	0.6944	9.33

Chapter 6 - Discussion

This paper develops an extended version of the theory of planned behaviour with the addition of environmental views as a potential predictor of the willingness for respondents to take FEA along with previous travel modes taken. The results show that the majority of the respondents are concerned about the environment and an even larger majority believe that the government should be investing more in sustainable transport. Other studies have shown that age has a positive impact on environmental concern (Liu et al., 2014) however age did not significantly influence respondents' attitudes in the survey. Most of the participants surveyed would consider FEA a viable alternative to taking the train or car and would advise others to use FEA. Following on from the results presented in the previous chapter the results will be further discussed and related to previous studies and also what they may mean for future studies and the potential for FEA.

Turning first to the hypotheses, none of the three could be rejected, the first hypothesis revealed that the only dependent variables from the TPB to influence the intention to use FEA were attitudes and social norms. However, given the small sample size it may be that if there were more time to perform the survey more of the factors would have been found to be significant. FEA was perceived more favourably in terms of convenience compared to taking the train though not as convenient as travelling by car. Subjective norms significantly influenced the decision to take FEA with most participants saying their family would approve of them using FEA, subjective norms have also been found as an important factor for sustainable behaviour in other studies (Si et al., 2020). As FEA is a new transport mode this may be a particularly important finding as the more people come acquainted with it the more opinions of family and friends will be shared and consumers will find their opinions important when deciding to use it themselves or not. The fact that FEA currently does not exist may have also caused issues for the respondents when considering the future potential use of such a travel option, however, the research overall does show that the majority of participants would indeed consider using FEA. Price may not be so much of an important factor for individuals than was the case in other studies for transport mode choice, with many participants saying that is sustainability a more important consideration than price, similar results were also found by Gaker et al. (2011). Though at the same time income did have an influence on the intention to take FEA with higher income having a negative influence on the intentions to use FEA.
The second hypothesis considered the influence of previous travel behaviour on the intention to use FEA, participants were asked how many round trips they had made by aeroplane, car and train in the previous year. The results showed that none of the previous travel modes significantly influenced the intention to take FEA when in the full model, though with the travel modes alone the previous year's number of flights taken did have a positive influence on the intention to take FEA. This may be due to the fact that taking FEA is similar to taking a conventional aircraft and so participants are already accustomed with flying and the process around it, meaning they can more easily envisage using FEA. It may also be that those who travel abroad by car already have a specific destination or type of holiday they go on and as these visits become more frequent the alternative

of flying becomes less appealing, for example Dijst et al. (2005) find a sizeable number of second homeowners travel between the Netherlands and Germany by car. Groningen being situated so close to the German border may also explain why certain individuals went so frequently on round trips abroad and these may simply be much more convenient by car than by other means of transport. The current transport mix in a city is therefore an important factor when considering the viability of FEA in a city as it may be that new potential destinations are already well-served by other transport means. It would be of use in future to determine the type of trips made with current transport modes in order to determine what sort of travellers are making these trips as this may make travel time, for example, and costs more or less important when making travel decisions. This may also help determine the potential economic benefits the city may or may not receive, whether it be better connectivity for business customers or greater levels of tourism. In terms of the correlation of the previous years' transport modes on the underlying factors, both environmental views and attitudes towards FEA are slightly influenced by the previous years' transport usage. Environmental views are negatively influenced by the respondents' car usage in the previous year. Attitudes towards FEA is positively influenced by the amount of plane travel taken in the previous year. The current transport usage for a city therefore is an important factor in gauging the potential demand for future transport modes and attitudes towards them.

The third hypothesis stated that FEA will be more popular over longer distances as the relative advantage of shorter travel times compared to other transport modes increases. When comparing a scenario from Groningen to Hamburg and Groningen to Frankfurt (around twice as far) FEA was more popular compared to taking the train and travelling by car in the second scenario than the first. The relative importance of the factors in the model also differs between the two scenarios, with environmental views becoming more influential with the greater distance and price sensitivity less influential. This echoes the research of Román et al. (2007) who found that taking the train in Spain was more popular over shorter distances than travelling by air and similarly LaMondia et al. (2016) who find aviation to be more popular at longer distances compared to self-driving cars. Initially FEA will only be able to fly shorter distances directly, the survey revealed that on average participants were more likely to choose FEA when the time savings were higher compared to other transport options (scenario 4 to Frankfurt being the most favourable for FEA compared to both train and car) and being further away than the closer proposed scenario to Hamburg. As the technology for FEA improves and range increases it may be that it becomes increasingly viable compared to the likes of driving or travelling by train. This is something policy makers should bear in mind when looking to the future transport needs of cities with secondary airports.

The research was conducted during the covid-19 pandemic, a very disruptive period for travel and especially international travel. Air travel was particularly hard hit and this may have influenced some of the participants' views towards air travel as it was seen by many as being less safe than taking the train and particularly travelling by car. It is yet to be seen if the pandemic has had lasting effects on the aviation industry though airlines are predicting (IATA, 2022) that

passenger levels will overtake pre-pandemic levels within the coming years suggesting that those initial reluctances are abating. The analysis could have been improved upon through having more respondents in order to increase the reliability of the analysis, however this was not possible given the timer scale for the study. Furthermore, in future it would be of use to perform a full decision model to analyse the various parameters when choosing between different transport modes in order to gauge more thoroughly where FEA fit in the complete transport mix so that investments can be made where customers are most likely to make use of them.

Regions should be preparing for the possibility of FEA becoming a viable alternative to cars and trains for medium journeys to cities which are currently not connected by flight, at least initially FEA will have the biggest impact where it relatively saves the most time for consumers, so not for very short flights but those long enough to reap the benefits of the shorter travel time. As the technology improves and the range increases more possibilities will become available, it is important for cities to thus plan ahead to avoid having a similar fate again with airlines potentially moving back to larger airports. There is thus potential that FEA could be a sustainable option in connecting secondary airports and thus achieving greater connectivity for regions and unlocking the full potential of smaller airports which in the last few years has seen a declining trend. Importantly this survey has shown that customers would be willing to travel with FEA and would also prefer to take FEA compared to the train or car and especially so where the journey times are much shorter. The aviation industry must cut its emissions to meet environmental goals and FEA may just be the solution to do so with the added benefit of reducing travel to and from larger airports and increasing connectivity to airports which have previously been unviable.

Chapter 7 - Conclusion

Fully Electric Aircraft have the potential to increase regional connectivity and help regional airports to contribute to regional development, where conventional aircraft have as yet been unable to do so. As the importance of reaching environmental goals increases industries will have to adapt and move towards a more sustainable way of operating if these goals are to be met. Fully Electric Aircraft development is one of the ways the aviation sector is preparing for the future with planned all electric aircraft running on renewable resources. The new technology brings many challenges with it though may also open new opportunities for smaller operations and interconnectivity between regional airports. An important factor in the move to all electric aircraft is whether potential customers would be willing to use such technologies and where they would see it sitting amongst other environmentally sustainable transport options. This paper has aimed to answer the question of the willingness of these potential customers to use such a transport option and whether it will have broad appeal for individuals concerned about the environment and those less so. In the context of the city of Groningen such a transport option would be welcomed especially for flights that reduce the total travel time significantly compared to what is currently offered by taking the train or travelling by car. At the same time the current travel behaviour of the public should be considered as this was found in some cases to influence the decision to take FEA or not.

As the public's knowledge and perception of FEA increases and changes further studies should be taken out to see whether it still indeed is a travel option the public are willing to embrace. Further studies could look at the preferences of passengers for different airports when taking FEA into account and whether the potential shift away from larger airports would indeed be preferable. Furthermore, a discrete choice experiment could be conducted to find out the willingness to pay for such flights and whether travel time or price has more of an influence on their decision-making process for these new aircraft types.

It is important for regional and national governments to consider the effects of these new aircraft as they have the potential to connect cities by air that are not currently, potentially unlocking new tourism and business routes, especially for cities that are currently difficult to connect by rail and road. Currently there are debates regarding funding for regional airports and as FEA comes to fruition the argument for funding regional airports may become more convincing. However, there is still a lot of uncertainty around FEA with no aircraft manufacture currently producing the aircraft, no airworthiness certification, and no firm orders from airlines. Though this paper has shown that the public are willing to embrace FEA even with little knowledge about it. The majority of participants in the survey believed that the government should be investing more in sustainable transport, FEA would potentially be a good recipient of such funding with its potential to fully utilise secondary airports in a sustainable way, something which could be very beneficial to regions. FEA may bring about a revolution in aviation similar to how low-cost carriers disrupted air travel in the late 90s. How and when this may happen is still unclear, though this paper has shown that potential customers are willing to use such a transport option, an important first step in bringing fully electric aircraft to fruition.

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Appendix

Qualtrics Survey

Thesis survey

Start of Block: Introduction

Introduction Fully Electric Aircraft
Fully electric aircraft (FEA) look set to make flying 100% emission free between cities such as Groningen and Paris by 2025. These new smaller aircraft have the potential to open up new routes that were previously not commercially viable. These aircraft would aim to utilise airports such as Groningen Eelde. These services would compete with driving, rail and long-range bus options as well as existing air routes from major airports. Main features:
100% sustainable 400km range Competitive prices compared to current air fares The aim of the survey is to gauge public opinion around the use of this potential new technology.

End of Block: Introduction

Start of Block: Survey Introduction

The survey consists of 7 parts and should take no longer than 10 minutes. All results are anonymous and will only be used as part of this research.

Thank you in advance for taking part in this research!

Click 'Agree' to proceed to the first question (otherwise close the survey in your browser):

End of Block: Survey Introduction

Start of Block: Environment

1 - Environmental views

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not sure (6)
I believe that the planet is threatened by climate change (1)	○	○	○	○	○	○
I try to make environmentally conscious decisions (2)	○	○	○	○	○	○
The environment is very important to me (3)	○	○	○	○	○	○
The government should invest more in sustainable transport (4)	○	○	○	○	○	○

End of Block: Environment

Start of Block: Price

2 - Price Sensitivity

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I would pay more for environmentally neutral transport (1)	○	○	○	○	○	○
Price is the most important factor when deciding upon transport options (2)	○	○	○	○	○	○
I would choose FEA even if it. is more expensive than a normal plane ticket (3)	○	○	○	○	○	○
I think sustainability is more important than price (4)	○	○	○	○	○	○
I think travel time is more important than price (5)	○	○	○	○	○	○

End of Block: Price

Start of Block: Subjective Norms

3 - Social Norms

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I feel I should choose greener transport options because my family/friends recommend it (1)	○	○	○	○	○	○
Those close to me would approve of using FEA (2)	○	○	○	○	○	○
Those whose opinions I value would choose FEA (3)	○	○	○	○	○	○
My friends would approve of me using FEA as an environmentally sustainable transport option (4)	○	○	○	○	○	○

End of Block: Subjective Norms

Start of Block: PBC

4 - Personal Control

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I have control over which means of transport I choose (1)	○	○	○	○	○	○
Booking flights is easy for me (2)	○	○	○	○	○	○
Booking trains is easy for me (3)	○	○	○	○	○	○
Travelling by car is easy for me (4)	○	○	○	○	○	○
I am able to decide myself whether take a train/ plane or drive (5)	○	○	○	○	○	○
I have the possibility to decide between different forms of transport (6)	○	○	○	○	○	○

End of Block: PBC

Start of Block: Attitudes

5 - Attitudes

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I would rather take FEA than drive for the same distance (1)	○	○	○	○	○	○
I would rather take a train than drive for the same distance (2)	○	○	○	○	○	○
I would rather take FEA than the train for the same distance (3)	○	○	○	○	○	○
I think travelling with FEA would be pleasant (4)	○	○	○	○	○	○
I find travelling by car pleasant (5)	○	○	○	○	○	○
I find travelling by train pleasant (6)	○	○	○	○	○	○
I would find FEA convenient (7)	○	○	○	○	○	○
I find travelling by car convenient (8)	○	○	○	○	○	○
I find travelling by train convenient (9)	○	○	○	○	○	○

I would find FEA comfortable (10)	○	○	○	○	○	○
I find travelling by car comfortable (11)	○	○	○	○	○	○
I find travelling by train comfortable (12)	○	○	○	○	○	○

End of Block: Attitudes

Start of Block: Intentions

6 - Intentions

Imagine you are travelling from Groningen to Hamburg (Roughly 200km). The prices are:

FEA - €60 Train - €50 Car - €55

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I would rather take FEA than travel by car for the same distance (1)	○	○	○	○	○	○
I would rather take a train than travel by car for the same distance (2)	○	○	○	○	○	○
I would rather take FEA than the train for the same distance (3)	○	○	○	○	○	○

Imagine you are travelling from Groningen to Frankfurt (Roughly 400km). The prices are:
FEA - €100 Train - €90 Car - €70
How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I would rather take FEA than travel by car for the same distance (1)	○	○	○	○	○	○
I would rather take a train than travel by car for the same distance (2)	○	○	○	○	○	○
I would rather take FEA than the train for the same distance (3)	○	○	○	○	○	○

Imagine you are travelling from Groningen to Hamburg (Roughly 200km). The total travel times are:

FEA - 2 hours Train - 2 hours Car - 2.5 hours

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I would rather take FEA than travel by car for the same price (1)	○	○	○	○	○	○
I would rather take a train than travel by car for the same price (2)	○	○	○	○	○	○
I would rather take FEA than the train for the same price (3)	○	○	○	○	○	○

Imagine you are travelling from Groningen to Frankfurt (Roughly 400km). The total travel times are:

FEA - 2.5 hours Train - 3.5 hours Car - 5.5 hours

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I would rather take FEA than travel by car for the same price (1)	○	○	○	○	○	○
I would rather take a train than travel by car for the same price (2)	○	○	○	○	○	○
I would rather take FEA than the train for the same price (3)	○	○	○	○	○	○

How would you rate the following statements:

	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Not Sure (6)
I would consider using FEA when it becomes available (1)	○	○	○	○	○	○
It is likely I would advise others to use FEA (2)	○	○	○	○	○	○

End of Block: Intentions

Start of Block: Personal Details

1.
7 - Demographic Questions

What is your residential location? (Municipality)

_____

2. What is your age? (Leave blank if you would prefer not to say)

_____

3. What is your income? (per annum)

- ○ Less than €15,000 (1)
- ○ Between €15,000 and €30,000 (2)
- ○ More than €30,000 (3)
- ○ Prefer not to say (4)

4. What is the highest level of education you have completed?

- ○ Primary School (1)
- ○ High School (2)
- ○ 'MBO' (3)
- ○ Bachelors Degree (4)
- ○ Masters Degree (5)
- ○ PhD (6)

5. What is your occupation?

- ○ None (1)
- ○ Student (2)
- ○ Unemployed - looking for work (3)
- ○ Unemployed - not looking for work (4)
- ○ Employed (5)
- ○ Self - Employed (6)
- ○ Retired (7)
- ○ Other (8)

6. How often do you usually travel abroad by train per year? Return trip counts as 1 (Non-Covid year)

_____

7. How often do you usually travel abroad by aeroplane per year? Return trip counts as 1 (Non-Covid year)

_____

8. How often do you usually travel abroad by car per year? Return trip counts as 1 (Non-Covid year)

_____

End of Block: Personal Details

Start of Block: Any comments?

Q27 Do you have any comments or suggestions for the survey? (If you would like to receive information on the results of this research you can leave your email address here).

_____

_____

_____

_____

_____

End of Block: Any comments?