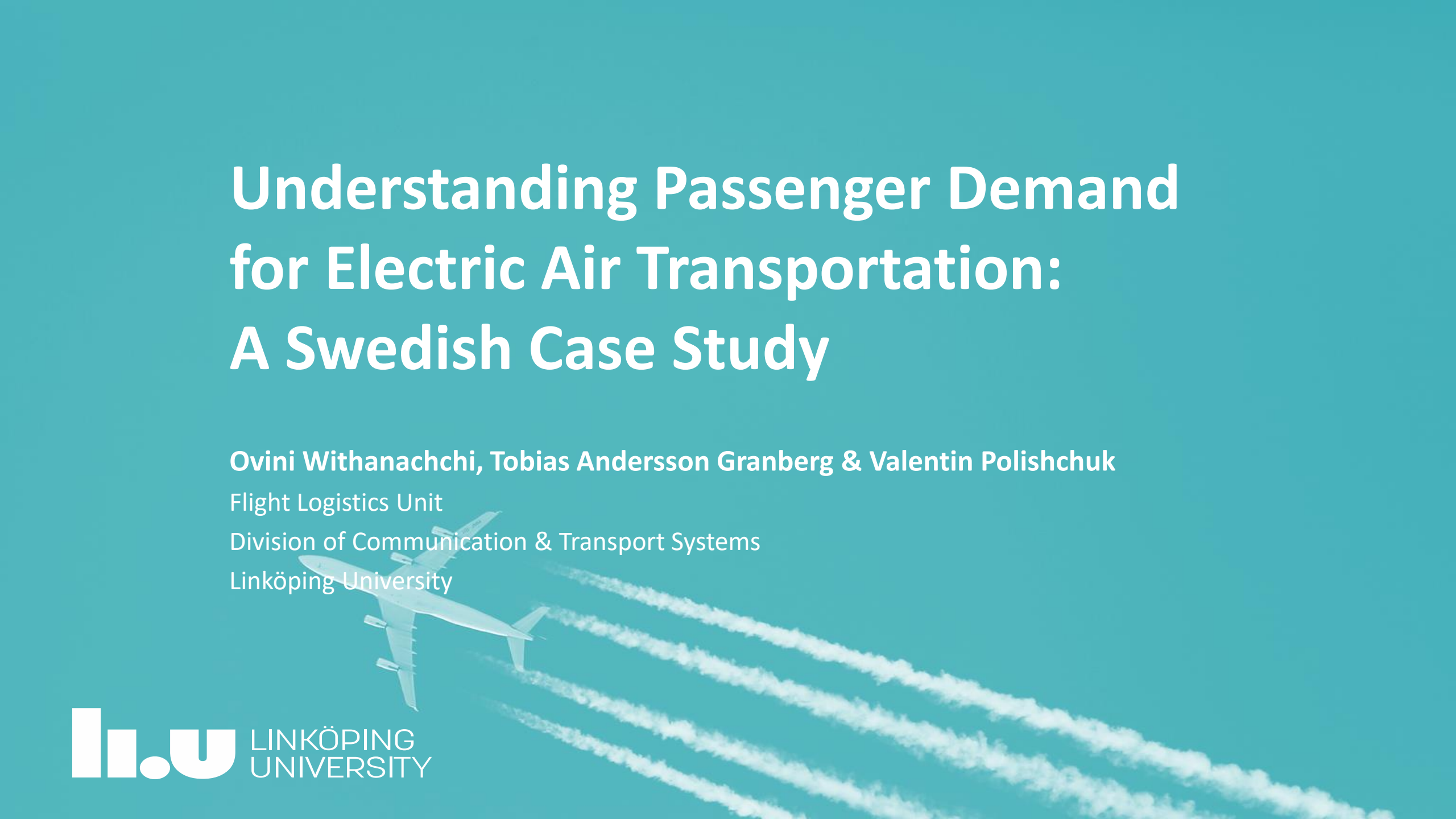
Understanding Passenger Demand for Electric Air Transportation: A Swedish Case Study

Ovini Withanachchi, Tobias Andersson Granberg & Valentin Polishchuk
Flight Logistics Unit
Division of Communication & Transport Systems
Linköping University



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Introduction



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Background



Aviation industry accounts for 2% of the global energy-related CO2 emissions



The overall global warming impact of the industry is even higher about 3.5%, due to the non-CO2 effects



The demand for air transport keeps increasing



One of the main industry objectives is to achieve net zero carbon emissions from international aviation by 2050. (ICAO)



Electric Aviation (EA) is one of many important solutions as part of this expected transition towards zero and low emission aviation.

Major Benefits of EA

- Reduced carbon emissions
- Reduced air pollution
- Reduced local pollution
- Noise reduction
- Energy efficiency
- Cost efficiency



Ideal Implementation Ground

- Geographical barriers
- Short distance routes
- World's cleanest energy mix
- Cheaper energy prices
- PSO routes

Pictures Source: Stock Images

Why Demand?

- Helps in realizing the **cost-effectiveness** of the EA operations.
- Provides insights about consumer preferences for EA such as **willingness to pay**.
- Helps in planning of the **necessary infrastructure** to support EA operations, such as charging stations at airports.
- Helps to understand the extent to which EA can contribute to **mitigating the environmental impact** of air travel
- Drives innovation related to electric aircraft technology and related infrastructure, **empowering advancements in the aviation industry.**

Aim & Research Questions



- Comprehensively analyze the factors that influence traveller choices and perceptions towards all-electric air transportation in Sweden.
- Construct a small-scale demand model that will serve as a proof-of-concept for potential data collection, model development, and analysis methods.

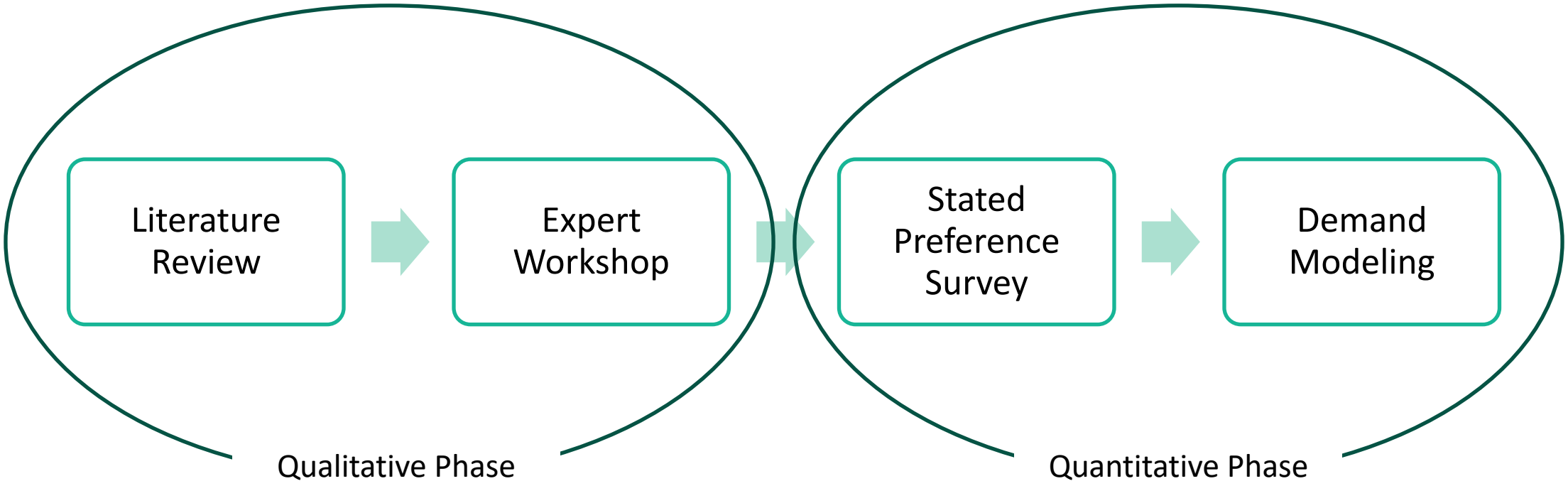


1. What factors determine passenger demand for electric air transportation in Sweden, and how do they impact that demand?

2. How can these factors be incorporated into demand modelling?

Methodology

The research design follows a mixed approach combining both qualitative & quantitative aspects.

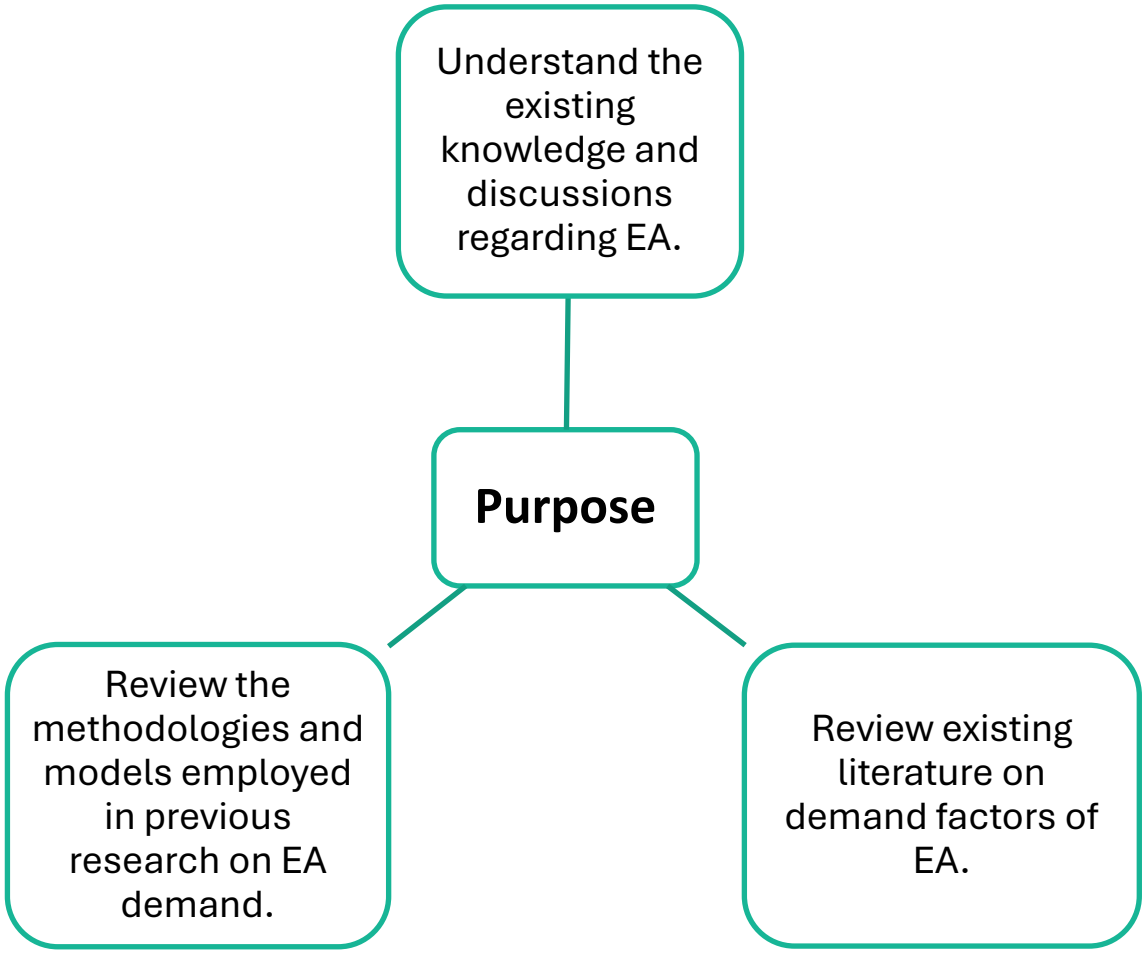


Literature Review



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Literature Review



Paper Categories

- Electric Aviation
- Conventional Aviation
- Urban Air Mobility (UAM)
- Electric Vehicles

Factors Influencing EA Demand

The preliminary list of factors obtained by the literature review is as follows.

Category	Factors
Economic	1. Gross Domestic Product (GDP) 2. Consumer Price Index (CPI) 3. Other (Exchange rate, PPP, FDI, fuel price)
Demographic	4. Population 5. Age 6. Gender 7. Income 8. Vehicle ownership 9. Land use 10. Number of households 11. Employment rate
Trip-related	12. Travel time 13. Travel cost 14. Distance 15. Alternative transport modes 16. Congestion 17. Trip purpose 18. Access/egress time 19. Waiting time

Category	Factors
Operational	20. Ticket price/airfare 21. Frequency 22. Size of the aircraft 23. Cruising speed 24. Range 25. Existing airport/vertiport location 26. Fleet size
Personal	27. Beliefs 28. Values 29. Attitudes 30. Subjective Norms 31. Perceived behavioural control 32. Value of travel time saving 33. Willingness to pay 34. Environmental awareness 35. Technological awareness 36. Safety
Other	37. Public policies/agreements

Expert Workshop



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Expert Workshop

- The workshop consisted of a panel of 6 participants from diverse professional backgrounds representing SAS airline, Swedish Regional Airports (SRF), Norrköping Airport, VTI (the Swedish National Road and Transport Research Institute) and Linköping University.

Workshop Objectives



Investigate more on factors influencing the demand for electric air transportation.



Discuss suitable modeling approaches to capture the demand for a new mode of transport.



Determine the input data and data sources required for modeling the demand.

Major Outputs

- Most & least relevant demand factors in the list according to the experts.
- New factors to be considered.
- Correlations between the factors
- Insights on the studied modeling approaches
- New directions for modeling approaches
- Insights on input data and data sources

Modeling Approach



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Modeling Approach

Model Selection

Discreet Choice Models

- Can begin at a simple and unconstrained point to model demand.
- Enables modelling personal choice.
- Allows the incorporation of electric aviation-specific factors.
- Allows the incorporation of other types of factors such as trip-related and demographics.
- The effect of each factor considered in the model can simply be obtained.
- Can easily be paired with SP surveys to quantify the qualitative factors.

Alternatives

Conventional Aviation & Electric Aviation

- The model was decided to be applied to the existing conventional aviation passenger movements between existing origin and destination airports.

Input Demand Factors

Trip Related Factors

- Travel Time
- Travel Cost (Ticket Price)
- Trip Purpose
- No. of Transfers

Personal/attitudinal Factors

- Environmental Concern
- Openness to New Technology
- Perceived Safety of a New Mode

Demographic Factors

- Age
- Gender
- Income

Data Collection Method

Stated Preference Survey

- Demonstrated more relevance to be used in the context of this study by solving the issues arising from not having historical data and quantification of qualitative personal factors.
- Usually be easily combined with the discreet choice models using the stated choice questions.

Stated Preference Survey



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Survey Design

- Travel frequency
- Trip purpose
- Factors they consider important when traveling by air
- Frequency of paying for climate compensation when buying an air ticket

To what extent do you agree/disagree with the following statements?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I consider the environmental impact when choosing a means of transport.	○	○	○	○	○
I enjoy using the latest technology and often try new innovations early on.	○	○	○	○	○
I am generally concerned about the safety of newly introduced technologies.	○	○	○	○	○

1 Previous Air Travel Experience

2 Personality/ attitude Related

Survey Design

3 Choice Scenarios

4 Demographics

Assume you are planning a one-way flight for you, considering the following details.

If both flight alternatives below are available to you, which would you choose?

Flight Alternatives	Conventional Aircraft	All-electric Aircraft
Origin & Destination	Stockholm to Gothenburg	Stockholm to Gothenburg
Purpose of your trip	Business	Business
Ticket Price	1800 kr	1800 kr
Travel Time	60 min	1hr 30 min
No. of Transfers	0	0
Personal Carbon Footprint	61 kg	5 kg
	○	○

- Age
- Gender
- Income
- Highest education level
- Employment status

Survey Data Collection

- The questionnaire consisted of a total of 22 questions per respondent which approximately takes about 5 minutes to complete.
- The survey was developed on a web-based surveying platform named LimeSurvey.
- The link to access the survey and QR code was shared with potential participants in our network through emails and other methods in July 2024.
- Survey responses were collected between July to August 2024 and received 84 full responses to make a testable data set.

Demand Model



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Model Development

- The study uses **Biogeme** which is a software specialized in estimating parameters of discrete choice models using maximum likelihood estimation (Bierlaire, 2018)

- It was decided to build two separate binary logit models considering the two trip purposes stated in the survey: leisure and business.

- The common practice of choice modeling to identify the best model was by developing multiple models and choosing the best out of them comparing their performance using log-likelihood values & t-test values.

- Several models were tested for each trip purpose, by including and excluding different explanatory variables in order to identify the best-performing model among the tested.

Model Results

Variable	Alternative	Leisure Purpose			Business Purpose		
		Model for Trip-related, Personal & Demographic Variables			Model for Trip-related, Personal & Demographic Variables		
		Beta	t-test	p-value	Beta	t-test	p-value
Alternative Specific Constant	EA	-2.290	-1.560	0.118	**-2.120**	**-1.820**	**0.069**
Ticket Price (value/SEK)	CA, EA	**-0.003**	**-7.820**	**0.000**	**-0.001**	**-6.800**	**0.000**
Travel Time (value/min)	CA, EA	**-0.044**	**-1.650**	**0.099**	**-0.040**	**-1.780**	**0.075**
Number of Transfers (value/transfer)	CA, EA	0.400	0.375	0.708	-0.226	-0.276	0.783
CO2 emission in CA (value/kg)	EA	0.038	1.350	0.178	0.037	1.700	0.089
Environmental Awareness	EA	**0.643**	**5.600**	**0.000**	**0.530**	**5.420**	**0.000**
Openness to Technology	EA	0.185	1.200	0.231	0.104	0.691	0.490
Safety Concern	EA	**-0.292**	**-2.150**	**0.032**	**-0.368**	**-2.730**	**0.006**
Income (value/SEK)	EA	0.028	0.313	0.754	0.044	0.558	0.577
Gender - Male	EA	0.438	1.550	0.120	0.386	1.550	0.121
Age	EA	0.146	0.977	0.329	**0.371**	**2.710**	**0.007**
Null Log Likelihood		-272.407			-309.837		
Log-likelihood of the estimate		-180.584			-214.6518		
ρ^2		0.337			0.307		

Scenario Analysis



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Scenario Analysis

- A scenario analysis was conducted in order to check the performance and the sensitivity of the developed model.
- Usually microsimulation of a population is conducted using synthetic sample.
- The synthetic population was generated in a way that mimicked demographic and personal/attitudinal data of the sample dataset obtained through the SP survey.
- Three O-D pairs were considered: Arlanda-Visby (A-V), Arlanda-Gothenburg (A-G) and Arlanda-Lycksele (A-L).
- Trip-related variable values were defined as required for each of the scenarios.

Scenario Analysis

1

Base Case

- EA prices are 20% higher
- 0 transfers for CA (direct flights)
- 1 transfer for EA as needed

		Leisure Traveller Model						Business Traveller Model					
		A-V		A-G		A-L		A-V		A-G		A-L	
		CA	EA	CA	EA	CA	EA	CA	EA	CA	EA	CA	EA
Base Case	Ticket Price (kr)	700	840	600	720	1100	1320	2100	2520	1800	2160	3300	3960
	Travel Time (min)	50	55	60	125	85	150	50	55	60	125	85	150
	Number of Transits	0	0	0	1	0	1	0	0	0	1	0	1
	CO2 emission of CA (kg)	45		61		75		45		61		75	

2

Introduction of a new environmental policy by the Swedish government

- CA Prices 10% higher

		Leisure Traveller Model						Business Traveller Model					
		A-V		A-G		A-L		A-V		A-G		A-L	
		CA	EA	CA	EA	CA	EA	CA	EA	CA	EA	CA	EA
CA prices higher by 10%	Ticket Price (kr)	924	840	792	720	1452	1320	2772	2520	2376	2160	4356	3960
	Travel Time (min)	50	55	60	125	85	150	50	55	60	125	85	150
	Number of Transits	0	0	0	1	0	1	0	0	0	1	0	1
	CO2 emission of CA (kg)	45		61		75		45		61		75	

3

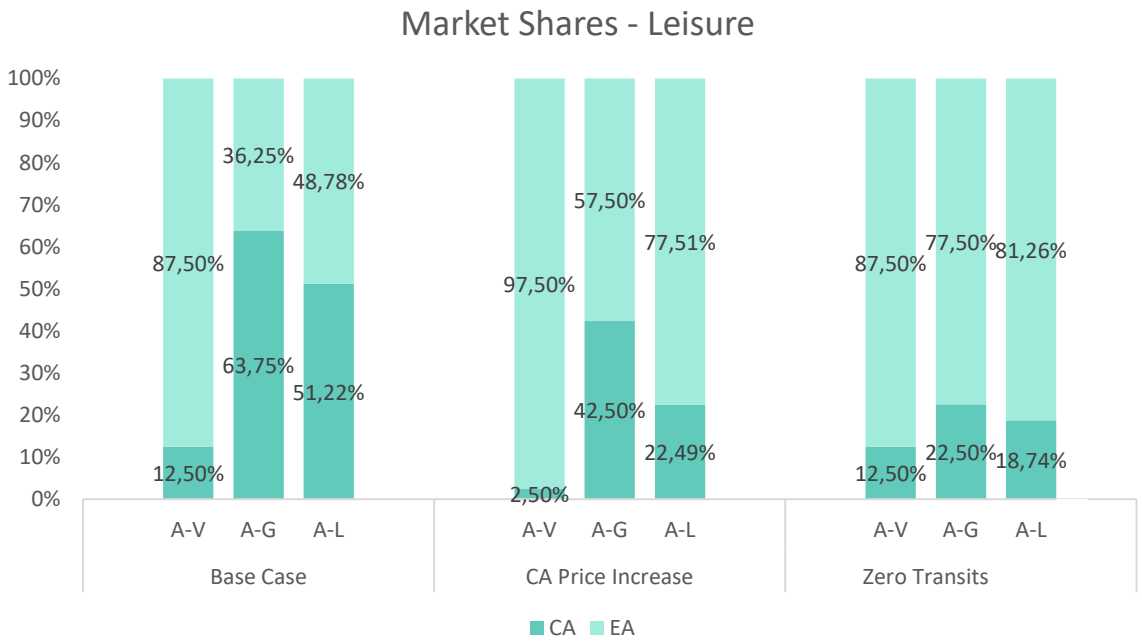
Technical characteristics of the EA are improved, and the aircraft range is increased.

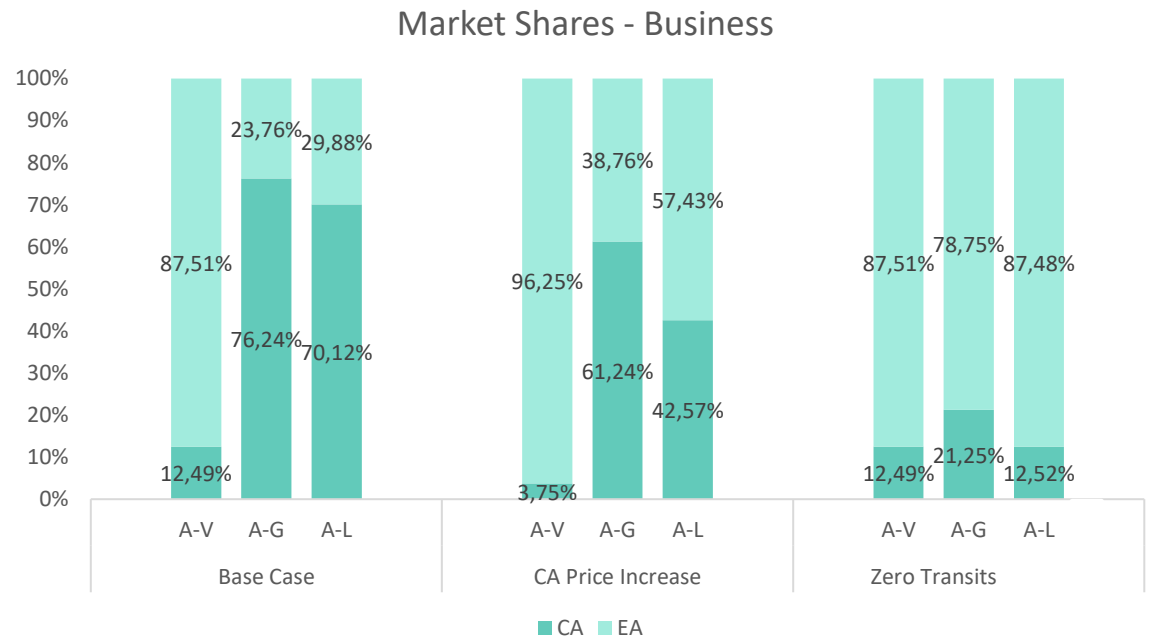
- 0 transfers

		Leisure Traveller Model						Business Traveller Model					
		A-V		A-G		A-L		A-V		A-G		A-L	
		CA	EA	CA	EA	CA	EA	CA	EA	CA	EA	CA	EA
Zero Transits	Ticket Price (kr)	700	840	600	720	1100	1320	2100	2520	1800	2160	3300	3960
	Travel Time (min)	50	55	60	90	85	115	50	55	60	90	85	115
	Number of Transits	0	0	0	0	0	0	0	0	0	0	0	0
	CO2 emission of CA (kg)	45		61		75		45		61		75	

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Scenario Analysis - Results





- Shorter routes demonstrate a high EA adoptability even with slightly higher prices
- CA domination in medium & long routes could be due to the longer travel time taken by EA.

- Leisure travellers were highly sensitive to the price changes.
- Business travellers were not as sensitive as leisure travellers to the price increase.

- Business travellers were more sensitive to the change in travel time and the number of transits than price.

Conclusions



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Conclusions

- Demand Factors in Two Models



- **Environmental concerns**
- Technological openness
- CO2 amount of CA
- Age
- Income
- Gender - Male
- No. of Transfers (Leisure Model)



- **Travel time**
- **Ticket price**
- **Safety**
- No. of Transfers (Business Model)

- Scenario Analysis



Relatively easy market share acquisition & higher adoption possibility for EA on shorter distance routes.



Medium & long-distance routes require not only price reductions but also reduced travel times and inconveniences.



Targeted strategies for different traveller groups.

- Model can be considered as a base model for proof of the concept

Current Work

- Refine and revalidate model using a large-scale survey which is more representative and diverse.

Survey Refinement

- 21 OD pairs
- Respondents have freedom to choose 3 OD pairs & the purpose most familiar to them
- More attitudinal statements
- Structural changes

Survey Deployment

- 15000 residents via postcards in Sep 2025
- Over 650 responses

Performance enhancement of the model

- Mixed Logit Models
- Latent Class Choice Models
- Initial basic MNL models show stable results
- High tendency to select EA




Hej, hjälp oss att besvara några frågor
i vårt forskningsprojekt!

Vi undersöker viljan att resa med batteri-elektriskt flyg
och dina svar är värdefulla för oss.

Svara på vår enkät
Via xxxxxxxxxx.se/xxxxxxxx eller QR-koden till höger får
du välja mellan olika resealternativ. Enkäten går snabbt att
besvara och är anonym.Varje person är slumpmässigt utvald
för att ge ett tvärsnitt av svensk befolkning, så enkäten ska ej
överlåtas till någon annan.

Läs mer om projektet
Besök liu.se/forskning/planering-av-flygtrafik/ean

Tack för din medverkan!
Tobias Andersson Granberg
Professor
Avdelningen Kommunikations- och transportsystem

We are investigating the willingness to travel with
battery-electric flights, and your answers are valuable
to us. The survey is available in English and Swedish.

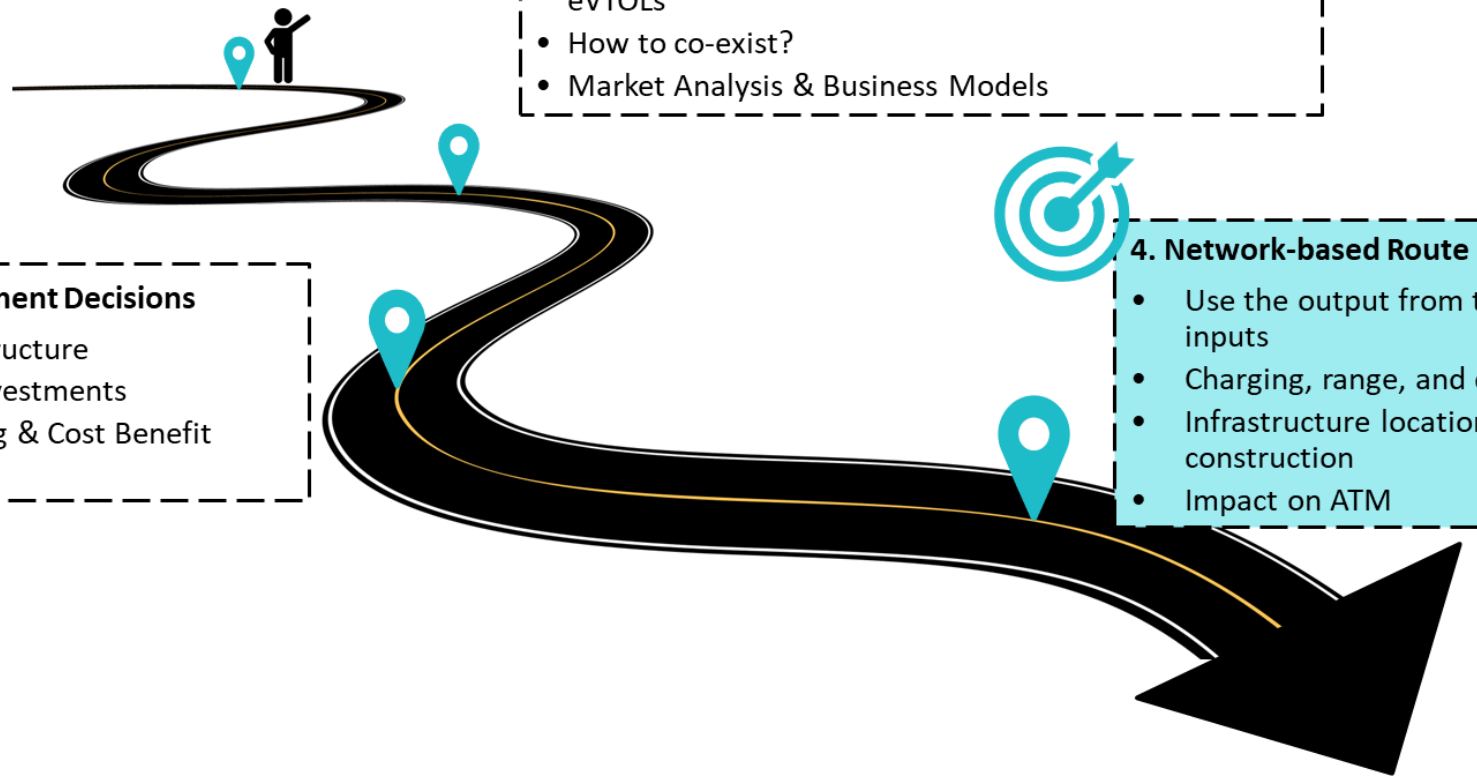
Future Work Road Map

1. Competition Adjusted Demand Estimation

- Demand modelling
- Identifying factors & impacts
- Competition with conventional aviation

2. Market Analysis & Joint Planning

- Conventional aircraft, fixed-wing electric aircraft and eVTOLs
- How to co-exist?
- Market Analysis & Business Models



3. Infrastructure Investment Decisions

- Use of existing infrastructure
- New infrastructure investments
- Optimization modeling & Cost Benefit Analysis

4. Network-based Route Planning

- Use the output from the previous steps as inputs
- Charging, range, and capacity constraints
- Infrastructure locations & network construction
- Impact on ATM

Thank you!



Ovini Withanachchi, ovini.wathma.withanachchi@liu.se
Tobias Andersson Granberg, tobias.andersson.granberg@liu.se
Valentin Polishchuk, valentin.polishchuk@liu.se

Electric Aircraft Network

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