



# Developments of Urban Air Mobility Analyses using Multi-Agent Transport Simulation

Ansgar Kirste and Eike Stumpf

Institute of Aerospace Systems (ILR)  
RWTH Aachen University  
Germany

*MATSim User Meeting 2023*  
*September 5<sup>th</sup> 2023*



- Potential new (on-demand) mobility system
- Low-noise and low-emission small electric aircraft
- **Electric Vertical Take-Off and Landing vehicles (eVTOL)**



Ehang 184



Airbus A3 Vahana



Joby S4



VoloCity



Aurora PAV



CityAirbus

# Motivation

## Urban Air Mobility

### ➤ Vehicle Level UAM

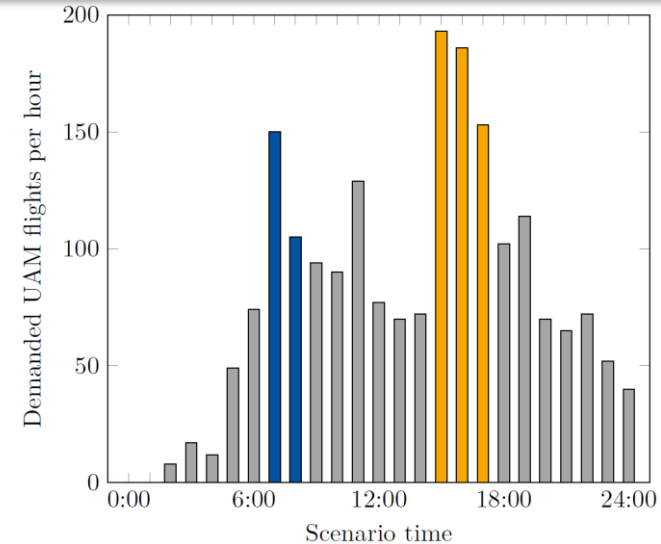
- Continuous development and analyses of eVTOL vehicles
- Studies on vehicle performance

### ➤ Air Transportation System Level UAM

- Market potential analysis
- Modeling of system interactions with competing modes of transportation





Airbus A3 Vahana





# Motivation

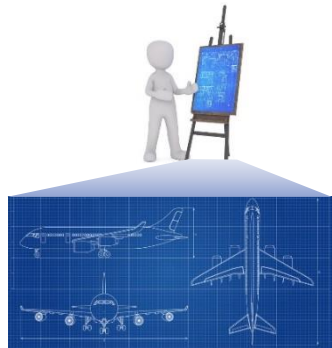
## Urban Air Mobility

### ➤ Vehicle Level UAM



-  Continuous development and analyses of eVTOL vehicles
-  Studies on vehicle performance

### ➤ Air Transportation System Level UAM

-  Market potential analysis
-  Modeling of system interactions with competing modes of transportation



## Aim of our research

-  **Decision tool** for implementing UAM systems
-  Overall UAM **sustainability** assessment

# Recent Research



MATSim UAM

Cost Model

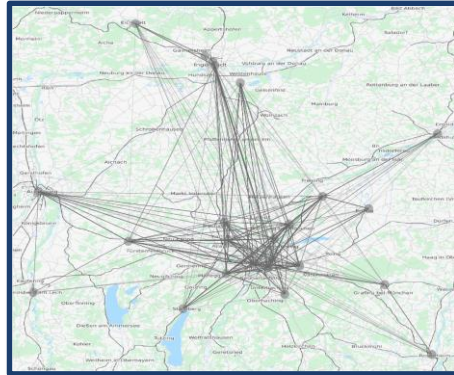
Price Loop

Sustainability

Current Work



Balac et al. [1]  
Rothfeld et al. [2-3]  
Horni et al. [4]



- Air mobility layer
- Access and egress legs
- Vertical flight segments (VTOL)

## Findings

- **Travel time savings** motivate UAM potential [3]
- Up to 1% modal split
- **UAM dispatcher** (used in postprocessing) allows reduction of vehicle fleet [5,6]

# Recent Research



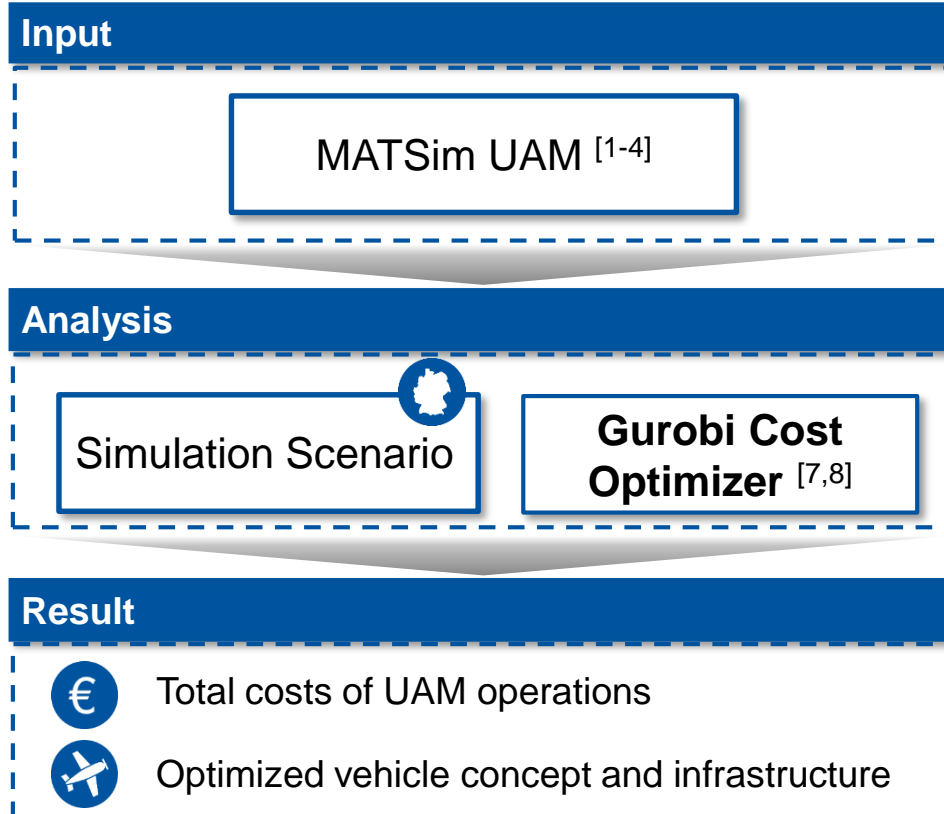
MATSim UAM

Cost Model

Price Loop

Sustainability

Current Work



**Referring to:**

Kirste, A., Husemann, M., and Stumpf, E., "Analysis of Sustainability Specifications of Urban Air Mobility Fleet Operations using Agent-based Transportation Simulation", *AIAA Aviation 2023 Forum*, 2023, <https://doi.org/10.2514/6.2023-3264>



# Recent Research



MATSim UAM

Cost Model

Price Loop

Sustainability

Current Work

→ Objective function: minimize **total costs** (TCO)

## Decision Variables

- eVTOL configuration
- Battery weight
- Recharging infrastructure

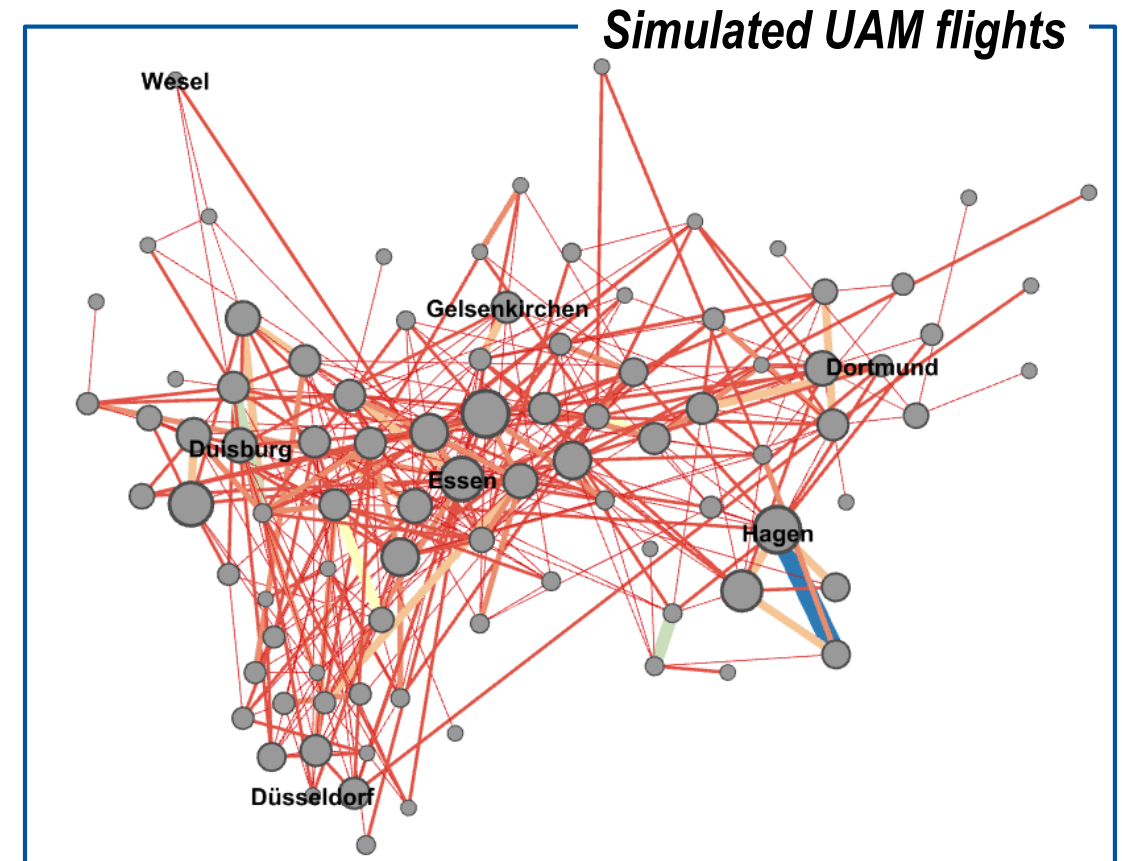
## Specifications

- Fleet costs
- Infrastructure costs
- Energy costs
- 3 segment flight profile

## Optimizer results (example) [7,8]

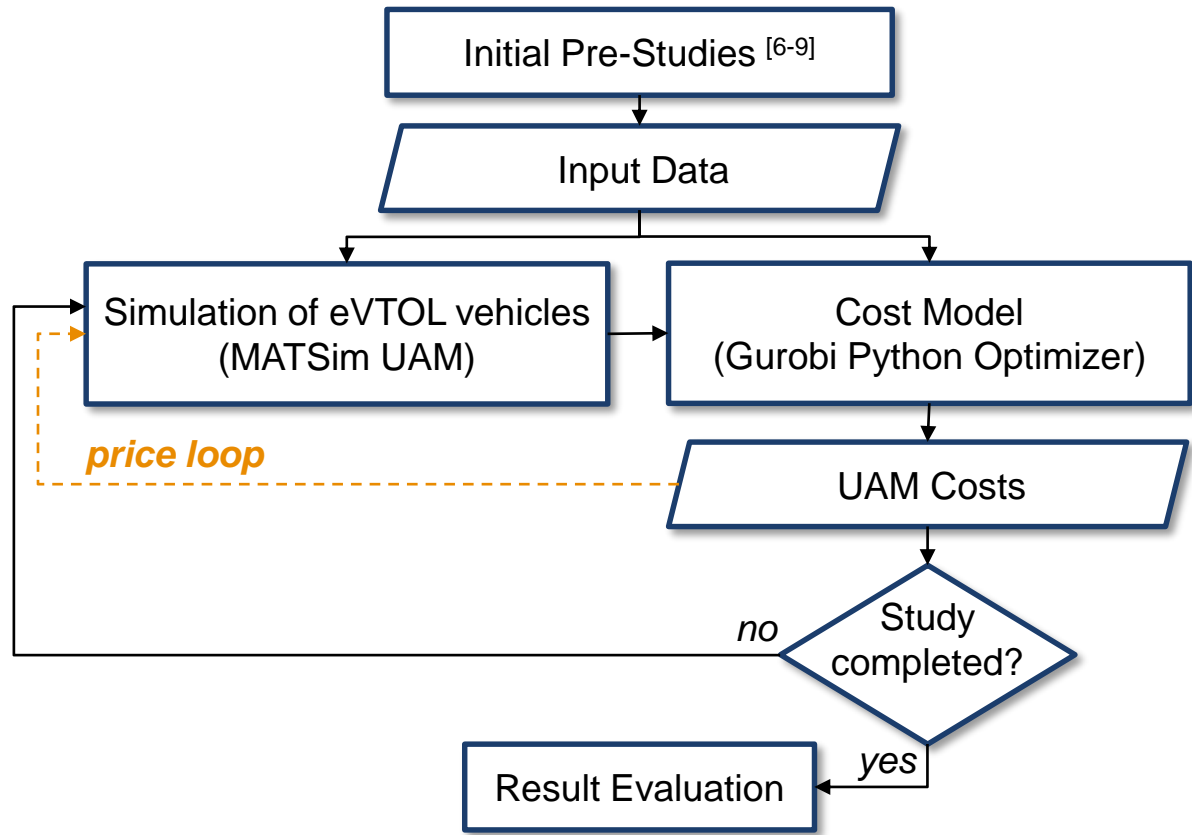
- Airbus Vahana concept
- 154 kg battery weight
- 150 kW charging facility

€ 1.50 € / pkm



Referring to [8]

# Recent Research



### Price loop [10]

- UAM trip prices are iteratively set to the optimized costs
- Requirement for **price convergence**: 3 consecutive simulations result in a similar price range (< 0.05 € / pkm)

Referring to:  
Kirste, A., Husemann, M., and Stumpf, E., "Analysis of Sustainability Specifications of Urban Air Mobility Fleet Operations using Agent-based Transportation Simulation", *AIAA Aviation 2023 Forum*, 2023, <https://doi.org/10.2514/6.2023-3264>



# Recent Research



→ Objective function: minimize **total costs** (TCO)

## Decision Variables


- eVTOL configuration
- Battery weight
- Recharging infrastructure

## Specifications

- Fleet costs
- Infrastructure costs
- Energy costs
- 3 segment flight profile

- + Cruise speed
- + **Station network**

- + UAM emission model
- + 7 segment profile
- + **Noise cost model**

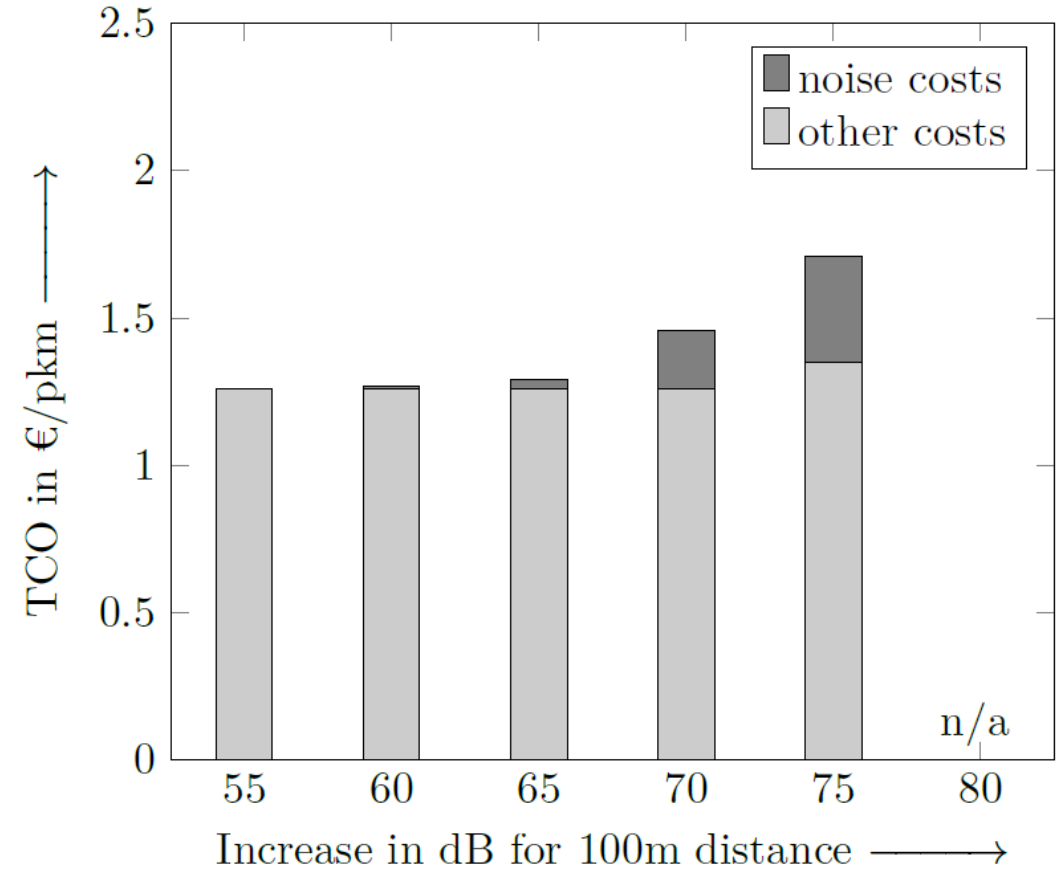
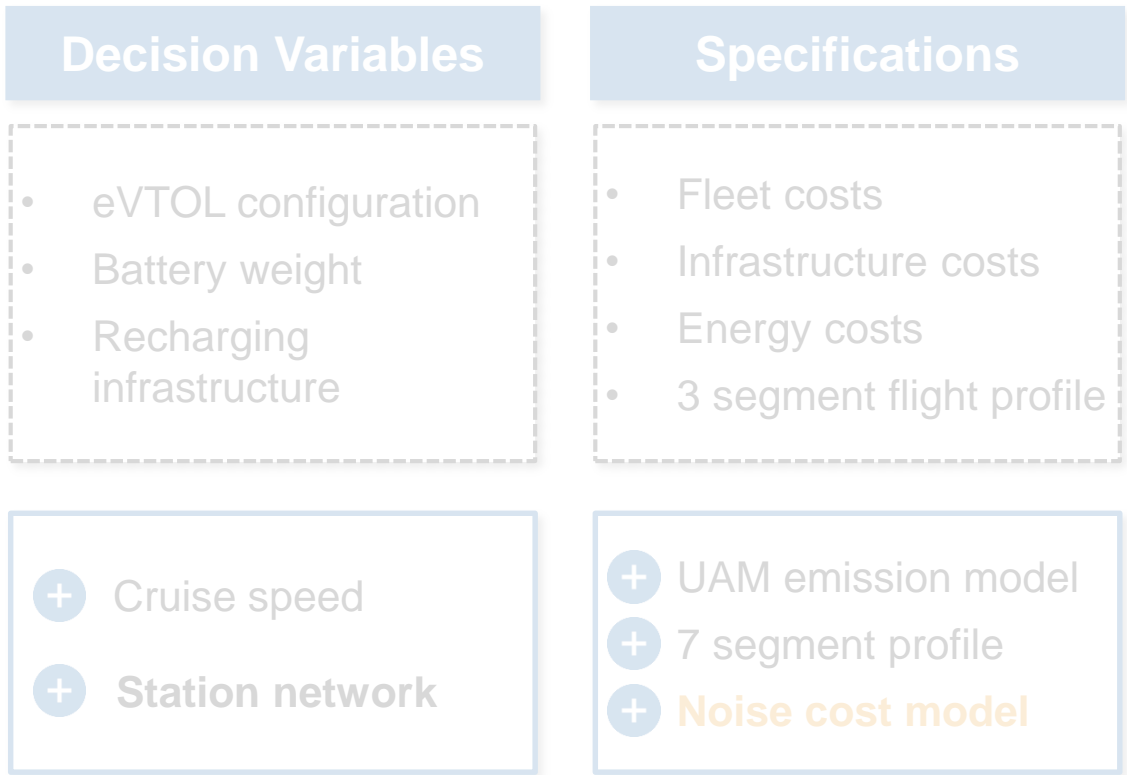
- 
- **Hedonic Pricing Method** <sup>[12]</sup>
  - Number of real estate properties linked to each vertiport option

Referring to [11]

# Recent Research



→ Objective function: minimize **total costs** (TCO)



Referring to [11]

# Recent Research



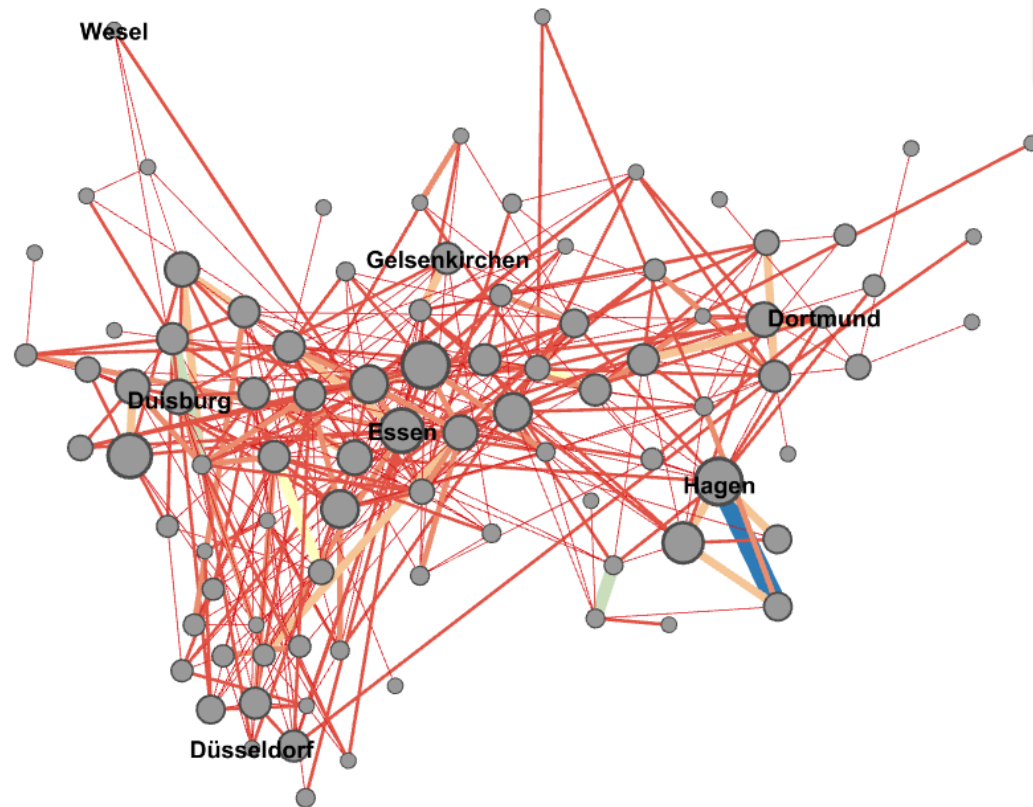
MATSim UAM

Cost Model

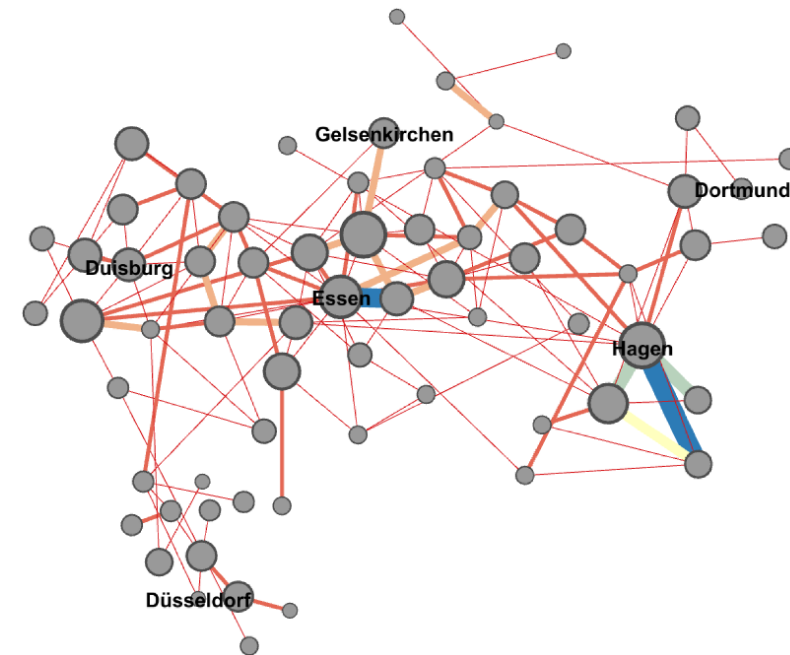
Price Loop

Sustainability

Current Work



➤ Total cost optimized network due to **noise emissions**



Referring to [8,11]

# Current Research



MATSim UAM

Cost Model

Price Loop

Sustainability

Current Work

→ Specifying MATSim UAM mode parameters [1-4,8]

## Early Approach

- Initial setting based on **public transport** [1-3]
- Rough estimation of UAM costs/pkm [8,10]

## Recent Approach

- **Iterative approach** of UAM costs/pkm [11]
- UAM Parameter setting in relation to **Choice-based-Conjoint** study [9,13]

## Current Approach

1. Mobility user survey combining both UAM and ground-based mobility
2. **Structural Equation Modeling (SEM)** [14]

## MATSim Level

- UAM mode parameter setting (**user acceptance**)
- Adapting **UAM dispatcher** for improved vehicle pooling

## Postprocessing Level

- Linking to **Life Cycle Assessment** of UAM vehicles
- Revenue Management instead of cost optimization

---

### ➤ Revenue Management

- Dynamic UAM price function in MATSim

## References (1/2)

---

- [1] Rothfeld, R., “Agend-based Modeling and Simulation of Urban Air Mobility Operation: An Evaluation of Travel Times and Transport Performance“, *Doctoral Dissertation*, Technische Universität München, 2021
- [2] Rothfeld, R., “Agend-based Modeling and Simulation of Urban Air Mobility Operation: An Evaluation of Travel Times and Transport Performance“, *Doctoral Dissertation*, Technische Universität München, 2021
- [3] Rothfeld, R., Fu, M., Balac, M., and Antoniou, C., “Potential Urban Air Mobility Travel Time Savings: An Exploratory Analysis of Munich, Paris, and San Francisco“, *Sustainability*, Vol. 13, No. 4, 2021, pp. 297-302. <https://doi.org/10.3390/su13042217>
- [4] Horni, A., Nagel, K., and Axhausen, K., “Introducing MATSim“. In: *Multi-Agent-Transport Simulation MATSim*, 2016. ISBN 978-1-909188-75-4
- [5] Husemann, M., Dirks, N., Stumpf, E., and Walther, G., “Towards the Design of Cost-Efficient Urban Air Taxi Systems“, *AIAA Scitech 2021 Forum*, 2021. <https://doi.org/10.2514/6.2021-1515>
- [6] Husemann, M., Lahrs, L., and Stumpf, E., “The impact of dispatching logic on the efficiency of Urban Air Mobility operations“, *Journal of Air Transport Management*, Vol. 108, 2023, p. 102372. <https://doi.org/10.1016/j.jairtraman.2023.102372>
- [7] Husemann, M., Kirste, A., and Stumpf, E., “Analysis of Cost-Efficient Urban Air Mobility Systems: Optimization of Operational and Configurational Fleet Decisions“, *European Journal of Operational Research*, 2023. <https://doi.org/10.1016/j.ejor.2023.04.040>
- [8] Kirste, A., Husemann, M., and Stumpf, E., “Analysis and Evaluation of Urban Air Mobility Fleet Operations using Agent-based Transport Simulation“, Paper presentation, *Deutscher Luft- und Raumfahrtkongress 2022*, 2022
- [9] Lotz, V., Kirste, A., Lidynia, C., Ziefle, M., and Stumpf, E., “User Acceptance of Urban Air Mobility (UAM) for Passenger Transport: A Choice Based Conjoint Study“, *Human-Computer Interaction International 2023 Conference*, 2023
- [10] Babetto, L., Kirste, A., Deng, J., Husemann, M., and Stumpf, E., “Adoption of the Urban Air Mobility System: Analysis of technical, legal and social aspects from a European perspective“, *Journal of the Air Transport Research Society*, Vol. 1, 2023. <https://doi.org/10.1016/j.paerosci.2023.100899>



## References (2/2)

---

- [11] Kirste, A., Husemann, M., and Stumpf, E., “Analysis of Sustainability Specifications of Urban Air Mobility Fleet Operations using Agent-based Transportation Simulation“, *AIAA Aviation 2023 Forum*, 2023, <https://doi.org/10.2514/6.2023-3264>
- [12] Kreimeier, M., and Franz, K., “Nachhaltigkeitsbewertung des Flugbetriebs für den Flugzeugvorentwurf“, *Deutscher Luft- und Raumfahrtkongress 2013*, Document ID: 301483, 2013
- [13] Klein, M., Lüpke, L., and Günther, M., “Home charging and electric vehicle diffusion: Agent-based simulation using choice-based conjoint data“, *Transportation Research Part D*, Vol. 88, 2020, p. 102475. <https://doi.org/10.1016/j.trd.2020.102475>
- [14] Burbach, L., Kojan, L., Ziefle, M., and Valdez, A. C., “SEM2Agent – A Scheme for the Use of Structural Equation Model Data in Agent-Based Models“, *Social Simulation Conference 2021*, 2021

# Thank you



**Ansgar Kirste**  
M.Sc.

Research Associate  
PhD Candidate



Wuellnerstrasse 7  
52062 Aachen | GERMANY

Tel +49 241 80-96803

[kirste@ilr.rwth-aachen.de](mailto:kirste@ilr.rwth-aachen.de)

[www.ilr.rwth-aachen.de](http://www.ilr.rwth-aachen.de)