Public Acceptance and Noise Considerations in Urban Air Mobility Research

Intermediate Results of DLR's HorizonUAM Project

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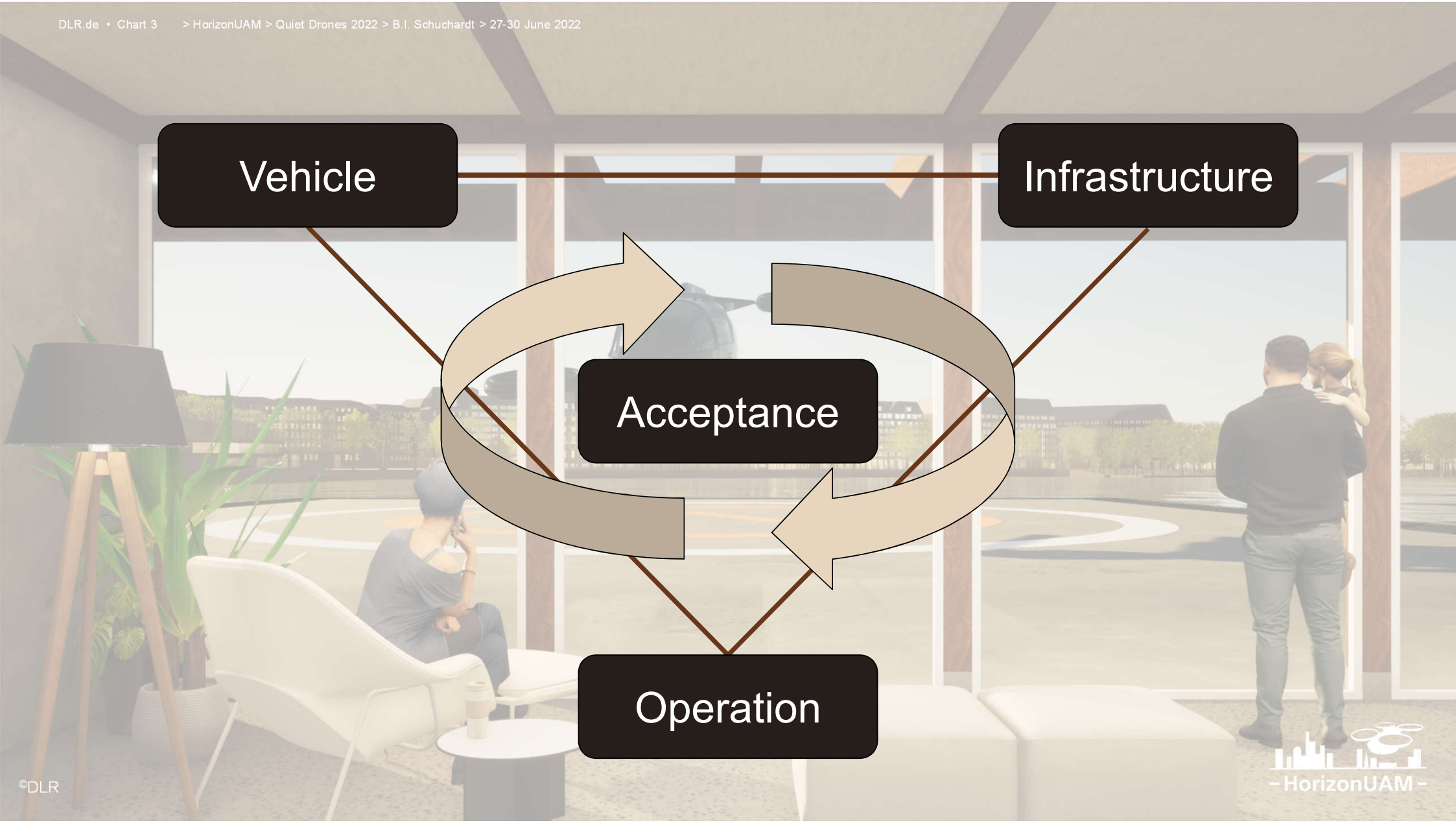
German Aerospace Center (DLR)

Quiet Drones
Second International e-Symposium
27-30 June 2022

DLR

HorizonUAM



Urban Air Mobility Research at the German Aerospace Center (DLR)

Objective: Assessment of chances and risks of air taxis and urban air mobility (UAM) concepts

Main content

- Forecast of UAM market share
- Model-based UAM system simulation
- Air taxi vehicle system development
- Flight guidance concepts for vertidromes
- Public acceptance
- Airport integration of UAM traffic
- Scaled flight demonstrations in model city

Duration: 07/2020 – 06/2023

Scope: 9.1 M€

Participants: 11 DLR institutes

Further reading:

- B.I. Schuchardt et al., Urban Air Mobility Research at the DLR German Aerospace Center – Getting the HorizonUAM Project Started, AIAA Aviation, 08.2021, https://doi.org/10.2514/6.2021-3197

Vehicle

HorizonUAM

Top Level Aircraft Requirements

System-of-system Simulation

Many Unknown Unknowns:

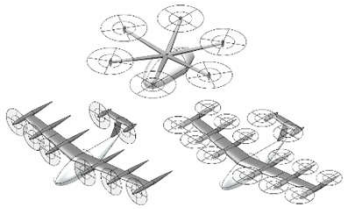
- TLAR of aircraft or fleet
- Homogeneous or heterogeneous fleet
- Point to point or hub & spoke
- Speed, range, etc.

To convert :
"Unknown" Unknowns
→ "Known" Unknowns
Agent based and discrete event simulation for vehicle/family design

For multiple scenarios
Multiple concept vehicles

Family of Vehicle Designs, Fleet and Architectures

Design Space Exploration



Family of Vehicles

Detailed Design

On Board Systems | Cabin | Propulsion

Further reading:

- P.S Prakasha et al., Tackling the Threat of Wildfires: Design and Assessment of Advanced Aerial Firefighting Fleets, DICUAM, 03.2022
- P.S Prakasha et al., Aircraft architecture and fleet assessment framework for urban air mobility using a system of systems approach, Elsevier Aerospace Science and Technology, Special Issue 'DICUAM 2021', 09.2021, https://doi.org/10.1016/j.ast.2021.107072
- P.S. Prakasha et al., System of Systems Simulation driven Urban Air Mobility Vehicle Design and Fleet Assessment, AIAA Aviation, 08.2021, https://doi.org/10.2514/6.2021-3200
- O. Bertram, Impact of different powertrain architectures on UAM vehicle concepts, DLRK, 09.2021

Infrastructure

HorizonUAM

Vertidrome Airside Level of Service

How do we decide if a vertidrome satisfies our requirements from an operational perspective?

Vertidrome Level of Service (VALoS) Concept

Who? → What? → How?

			Stakeholder Requirements			
		Reference	**Passenger**	**VTOL Vehicle**	**Vertidrome**	
VALoS	Acceptable	Flow [Processed Operations/ Time Interval]	$\varnothing\ d_{PAX}$	$t_{AFT} - t_{NFT}$	$\geq 95\ \%$ Flights $\leq d_{TF}$	Metric
			≤ 2 Minutes	≤ 5 Minutes	$d_{TF} = 2.5$ Minutes	Objective
	Non-Acceptable		$\varnothing\ d_{PAX}$	$t_{AFT} - t_{NFT}$	$< 95\ \%$ Flights $\leq d_{TF}$	Metric
			> 2 Minutes	> 5 Minutes	$d_{TF} = 2.5$ Minutes	Objective

Nomenclature

d=delay	NFT = nominal flight time
t = time (duration)	TF = total flight
AFT = actual flight time	PAX= passenger

Further reading:

- K. Schweiger et. al., An exemplary definition of a vertidrome's airside concept of operations, Elsevier Aerospace Science and Technology, Special Issue 'DICUAM 2021', 10.2021, https://doi.org/10.1016/j.ast.2021.107144
- K. Schweiger et al., Urban Air Mobility: Vertidrome Airside Level of Service Concept, AIAA Aviation, 08.2021, virtual, https://doi.org/10.2514/6.2021-3201

Vertidrome Airside Level of Service

How do we decide if a vertidrome satisfies our requirements from an operational perspective?

Vertidrome Level of Service (VALoS) Concept

Demand Distribution

Vertidrome Layout and Operational Concept

Insights about…

Processing Airside Performance

Resilience Capability

Behaviour of Flow Rates

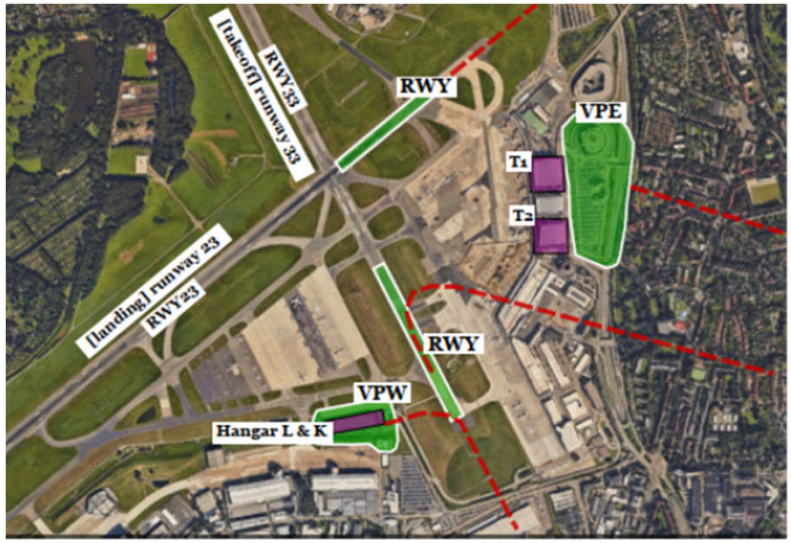
Degree of Stakeholder Satisfaction

Further reading:

- K. Schweiger et. al., An exemplary definition of a vertidrome's airside concept of operations, Elsevier Aerospace Science and Technology, Special Issue 'DICUAM 2021', 10.2021, https://doi.org/10.1016/j.ast.2021.107144
- K. Schweiger et al., Urban Air Mobility: Vertidrome Airside Level of Service Concept, AIAA Aviation, 08.2021, virtual, https://doi.org/10.2514/6.2021-3201

Operation

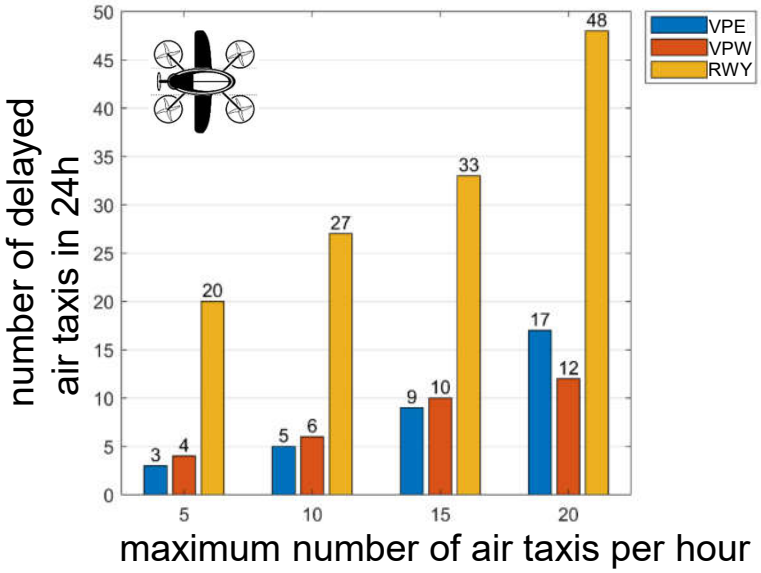
Impact of Air Taxis on Air Traffic in the Vicinity of Airports



Analytical model for air taxi (AT) operations at Hamburg airport based on fast time simulation

3 touchdown and lift-off areas (TLOF)

Energy consumption analysis of air taxis



Runway-Integration not advisable for medium traffic airports

Vertiport-Integration allows traffic volume up to 20 AT /h

Battery capacity shows bottleneck for AT operations

Further reading:

- N. Ahrenhold et. al, Impact of Air Taxis on Air Traffic in the Vincinity of Airports, MDPI Journal Infrastructures, 10.2021, https://doi.org/10.3390/infrastructures6100140

VPE = Vertiport East, VPW = Vertiport West, RWY = Runway Integration

Public Acceptance

HorizonUAM

Background: Drone Noise Assessment

- Recent study on „Noise Impact of Drone Operations on the Environment“, commissioned by German Environment Agency (Umwelt Bundesamt)
- Noise assessment for drones < 25 kg
  - Topics: Drone market, noise emission, noise impact, regulations, impact on society and nature, need for action

➢Very little valid noise assessments available, mainly for multicopters

➢Psychological investigations only under lab conditions

➢Pronounced tonality, easily distinguishable from other environmental/urban sounds, tonality should be decreased by design

ISSN 236-829X

Telephone Survey on the Acceptance of Civil Drones in Germany (2018)

- **Survey method**
  Computer-assisted telephone interviews (CATI)
- **Implementation:**
  infas GmbH (Bonn, Germany)
- **Number of cases:**
  n = 832
- **Average duration per interview:**
  18 minutes
- **Sample:**
  Drawn using a random digital dial design with
  landline and mobile phones
  (representative for the German population by weighting)


CEAS Aeronautical Journal (2020) 11:665–676
https://doi.org/10.1007/s13272-020-00447-w

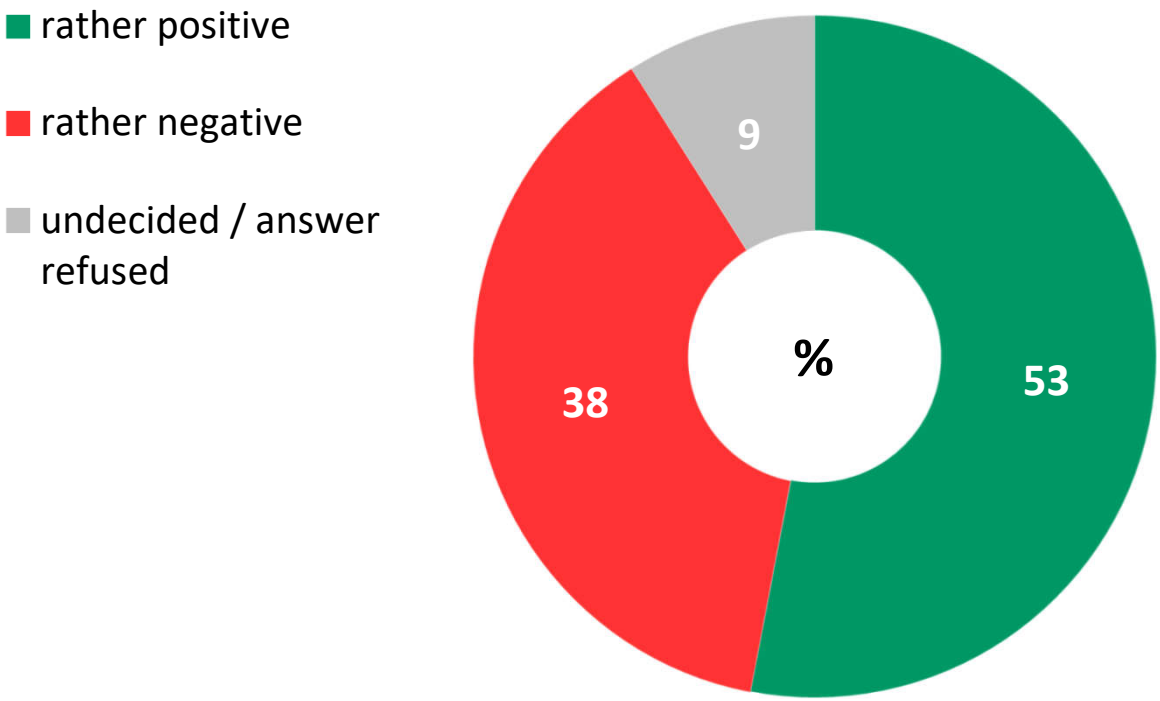
ORIGINAL PAPER

The acceptance of civil drones in Germany

H. Eißfeldt[1] · V. Vogelpohl[1] · M. Stolz[2] · A. Papenfuß[2] · M. Biella[2] · J. Belz[3] · D. Kügler[2]

Telephone Survey on the Acceptance of Civil Drones in Germany (2018)

General attitude towards civil drones

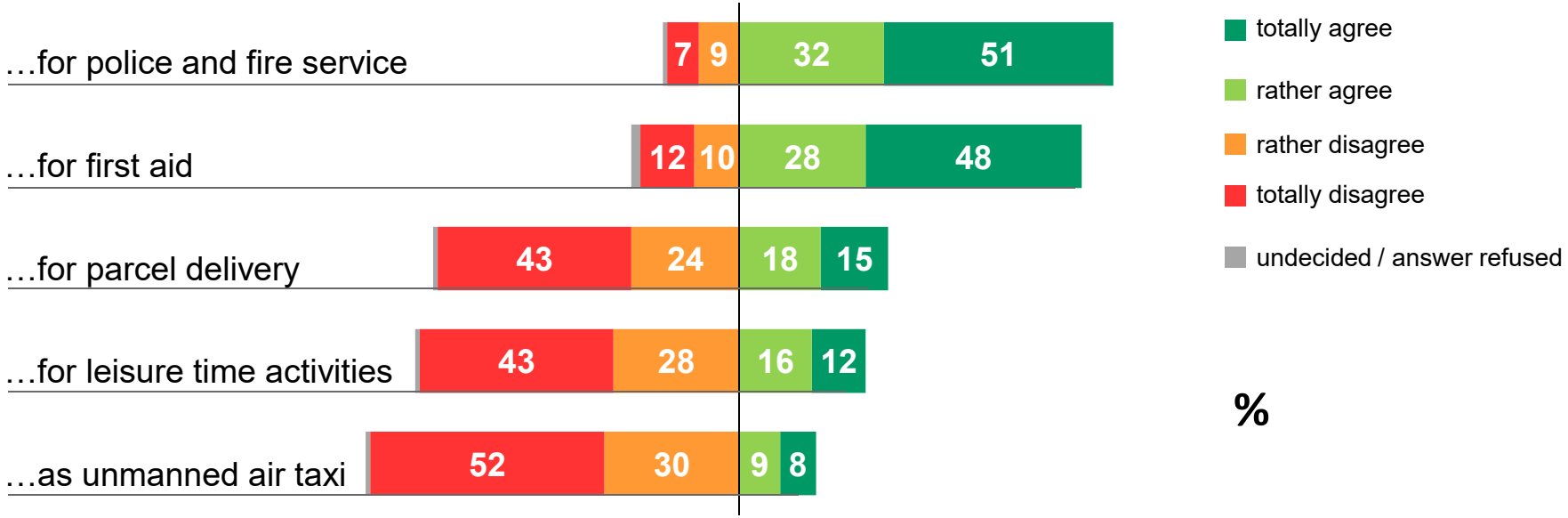


Attitude differed between subgroups, e.g. according to:

- Gender
- Age
- Knowledge about drones
- Experience (having already flown a drone oneself)
- Interest in modern technology

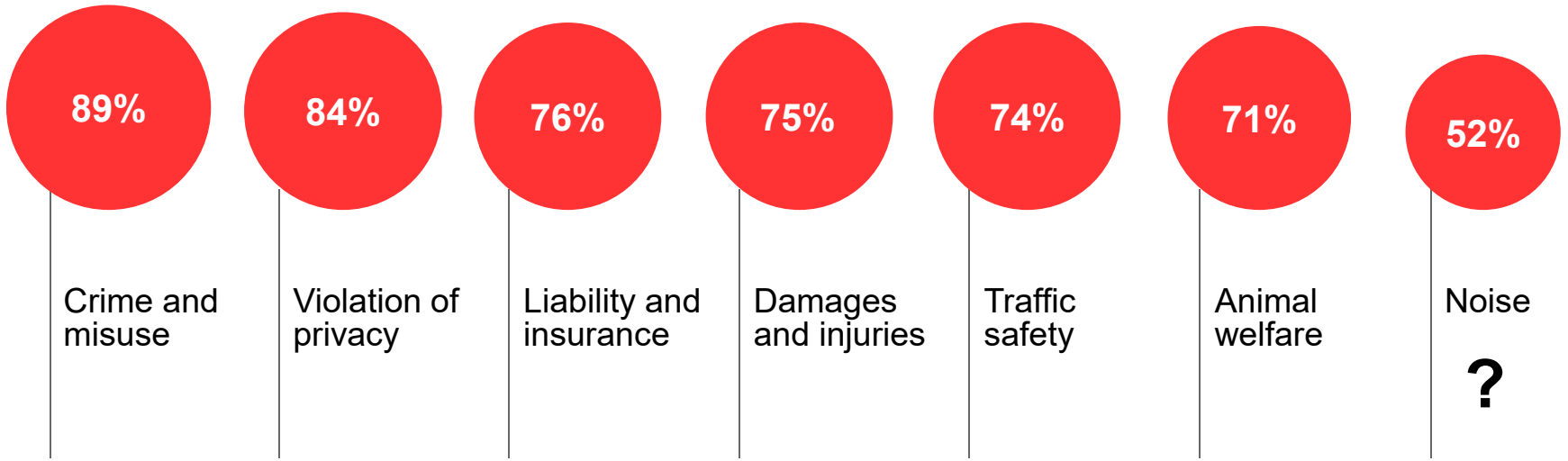
Telephone Survey on the Acceptance of Civil Drones in Germany (2018)

Envisioned own usage of civil drones



Telephone Survey on the Acceptance of Civil Drones in Germany (2018)

Areas of concern about civil drones



displayed = „rather concerned“

Telephone Survey on the Acceptance of Civil Drones in Germany (2018)

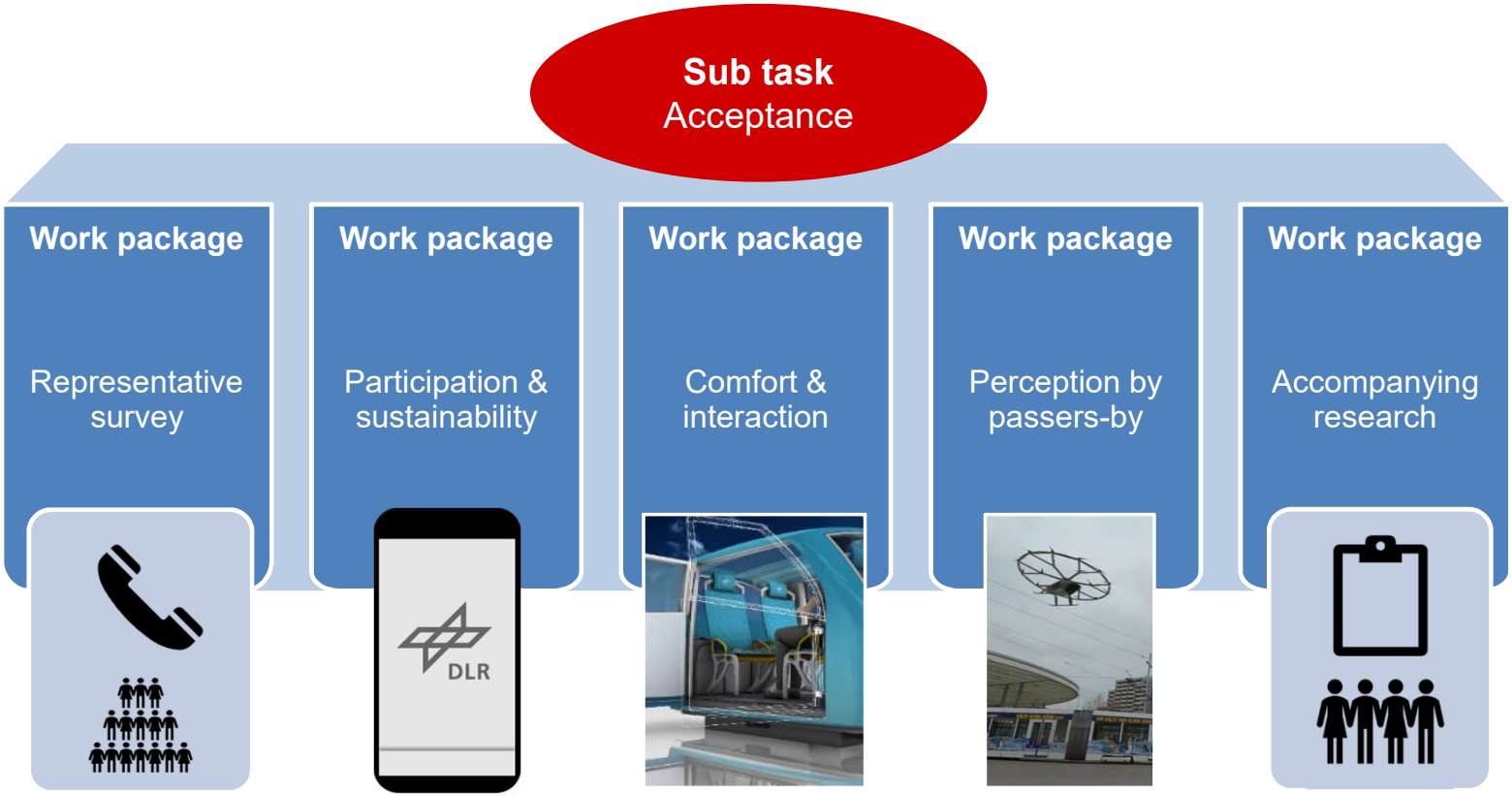
Areas of concern about civil drones

But:

- Noise concerns tended to occur more frequently among those who had already heard a drone ($\chi^2[1] = 3.29$, $p = .07$)
- Chi-square automatic interaction detection (CHAID):
  Noise concerns explained the general attitude towards civil drones best among all seven assessed concerns ($\chi^2[2] = 38.6$, $p < .001$)

Further reading:
- H. Eißfeldt, et. al, The acceptance of civil drones in Germany, CEAS Aeronautical Journal, 03.2020, https://doi.org/10.1007/s13272-020-00447-w

Sub task Acceptance of DLR's HorizonUAM project



Representative Survey

Approach
- Telephone survey on the acceptance of civil drones in Germany (planned *n* = 1000)
- External market/social research institute → computer-assisted telephone interviews (CATI)
- Focus on noise related aspects, air taxis, and potential changes in opinion (vs. 2018)

Preparatory workshop
- Held in 12/2020 with experts in the field of drone acceptance
- Participants from DLR & several German research institutes and city authorities

Supplementary analyses
- Of the data from 2018 → conference papers

Further reading:
- A. End et al., Gender differences in noise concerns about civil drones, ICBEN, 06.2021
- H. Eißfeldt, A. End, Sound, noise, annoyance? Information as a means to strengthen the public acceptance of civil drones, InterNoise, 08.2021, doi: 10.3397/IN-2021-2045

Current status
- Questionnaire has been created, public tender has taken place

Participation & Sustainability

Approach

- Developing a smartphone app with three features:
  - Graphical representation of UAM flight track data
  - (Objective) UAM noise measurements
  - (Subjective) UAM noise assessments
- External IT service provider for programming
- Testing the app at DLR's National Experimental Test Center for UAS in Cochstedt

Benefit

- Opportunity for adapting flight routes/profiles such that UAM noise can be distributed as fairly as possible among residents

Current status

- Draft of app and its functions has been created

Further reading:

- H. Eißfeldt, Sustainable Urban Air Mobility Supported with Participatory Noise Sensing, Sustainability, 12 (8), 2020, doi: 10.3390/su12083320

Perception by Passers-by

Approach

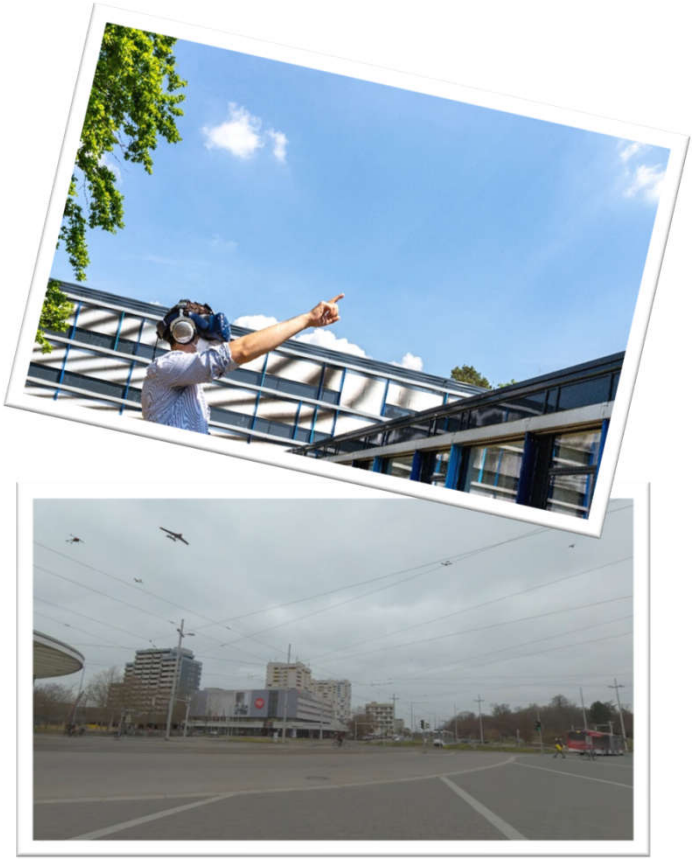
- Determining the perspective of passers-by experiencing drones virtually flying above the city of Braunschweig (incl. an air taxi landing)
- Exp. factors: flight levels, visual density, and presence of UAM sound
  (for a similar approach at NLR, see Aalmoes & Sieben, 2021, DICUAM)

Technical setup

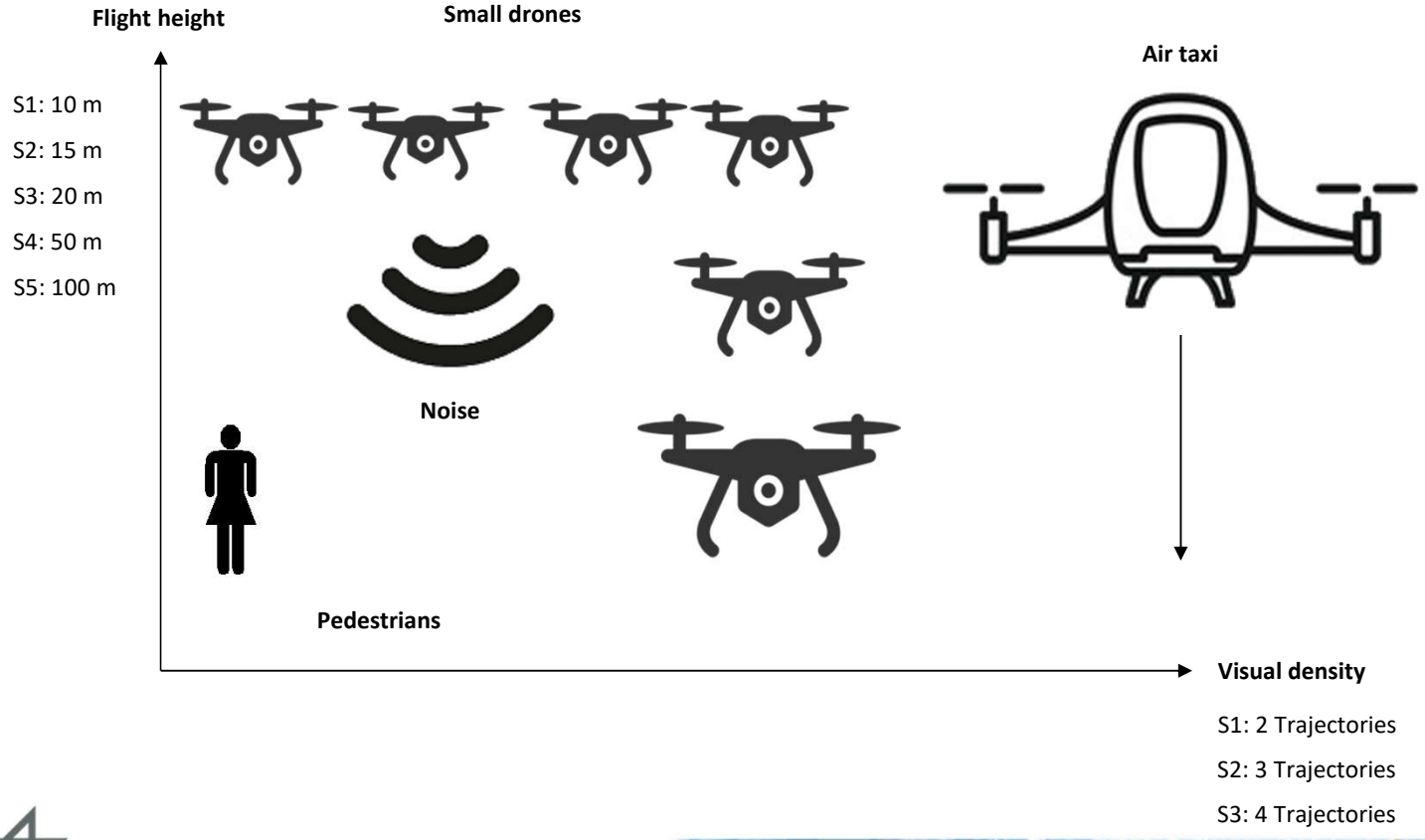
- Integration of drones into 360° video of an urban scene from Braunschweig presented to participants in VR from the pedestrians' point of view

Current status

- Data collection and analysis have been completed
- Conference contribution for DASC 2022 is being prepared



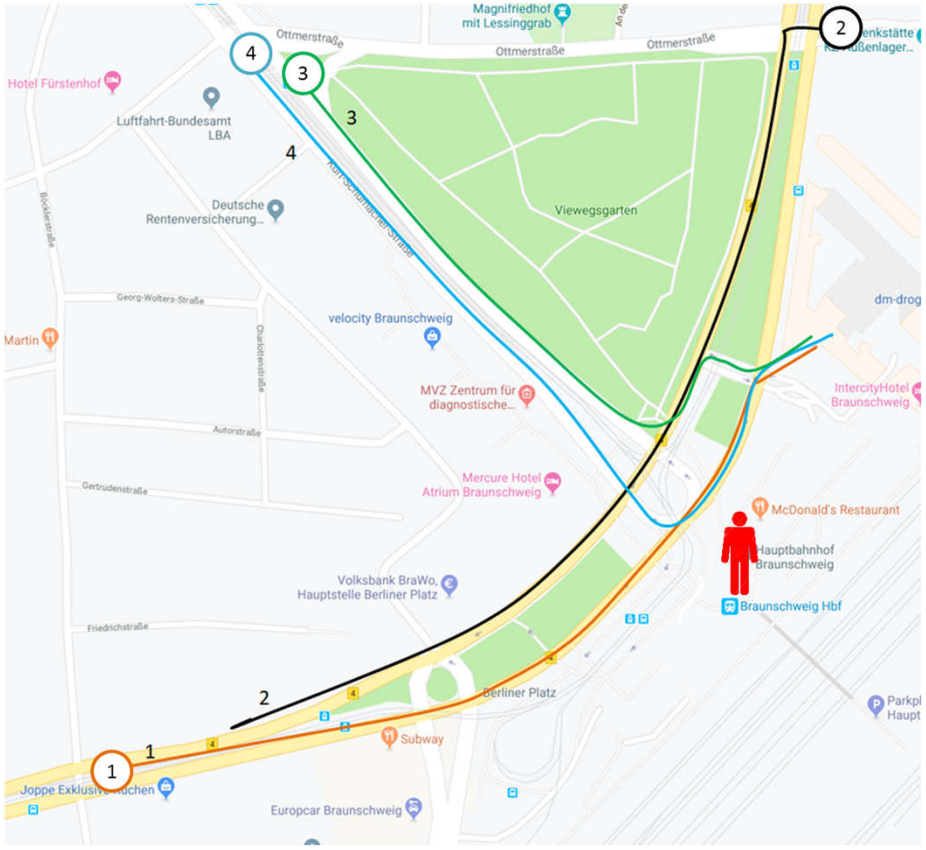
Method - Scenarios and Study Design



18 scenarios:

- 1 Baseline scenario
- 5 flight height scenarios (+/- sound)
- 3 visual density scenarios (+/- sound)
- Air taxi scenario

Method - Trajectories



Trajectories of the drones and viewpoint of the participants (red manikin)

1 = Trajectory 1

2 = Trajectory 2

3 = Trajectory 3

4 = Trajectory 4

Drone models

Visualization

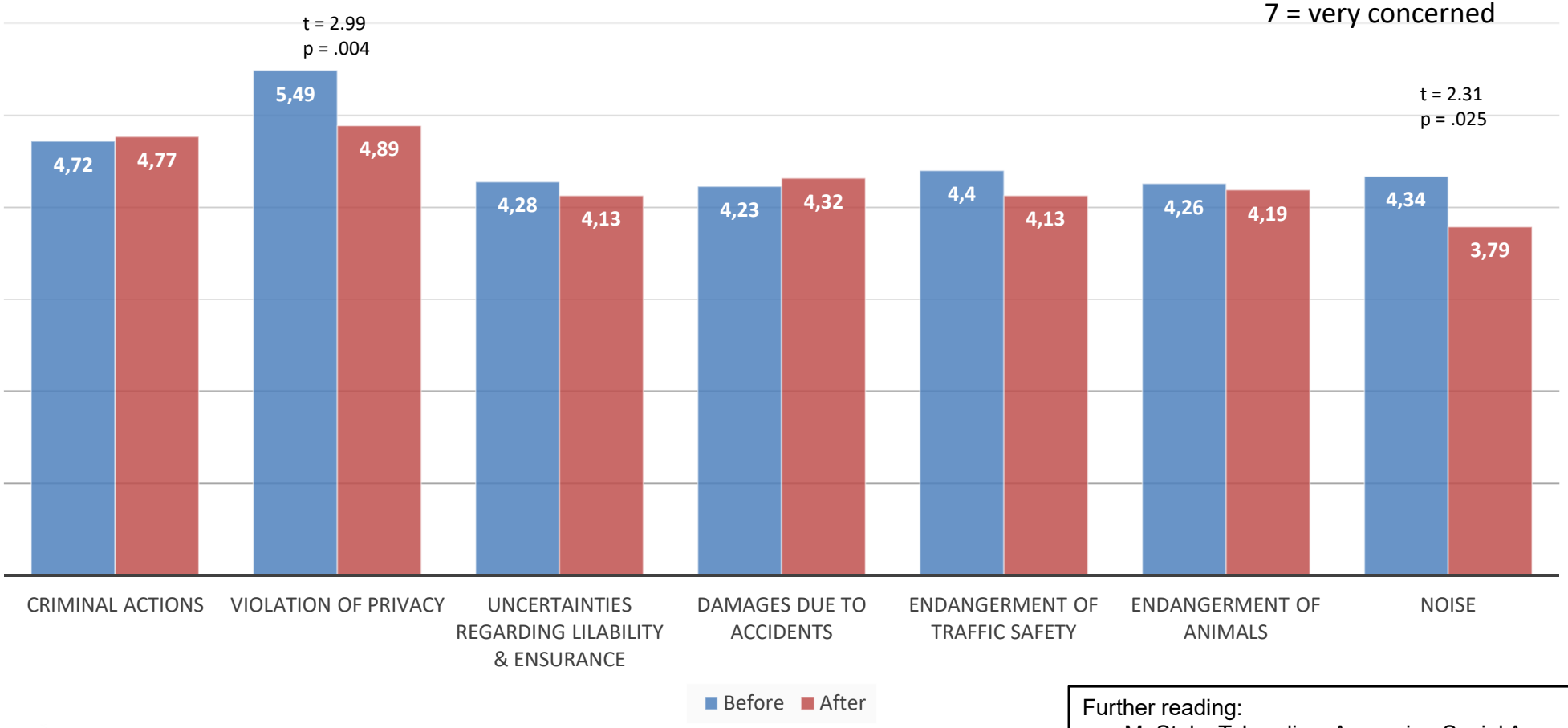
Visual density scenario with 4 trajectories

Air taxi scenario

Results on Public Concerns

1 = not concerned at all

7 = very concerned



Further reading:

- M. Stolz, T. Laudien, Assessing Social Acceptance of Urban Air Mobility using Virtual Reality, DASC 09.2022 (accepted for publication)

Comfort & Interaction

Approach

- Determining the perspective of passengers experiencing a virtual flight with an air taxi
- Focus on examining wellbeing and interaction depending on presence/absence of pilot on board, different amounts of available information, and flight route rescheduling after take off
- Airport shuttle use case (Hamburg city center → Hamburg airport)

Technical setup

- Combination of UAM cabin simulator and mixed reality visual system

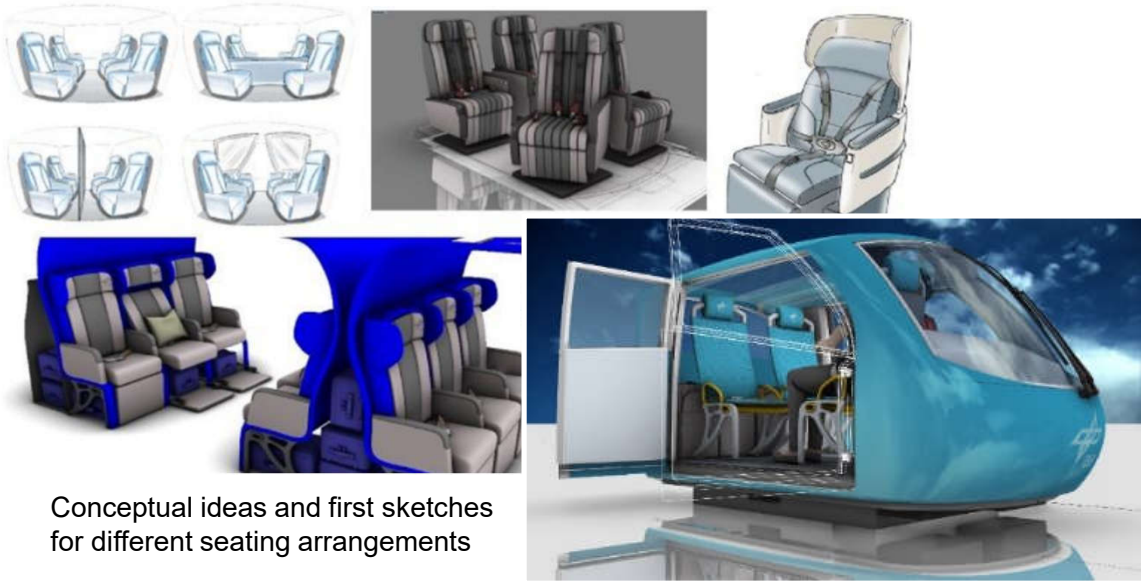
Current status

- Study has been conceptualized (incl. experimental design & flight scenarios)
- Virtual simulation environment is currently being set up

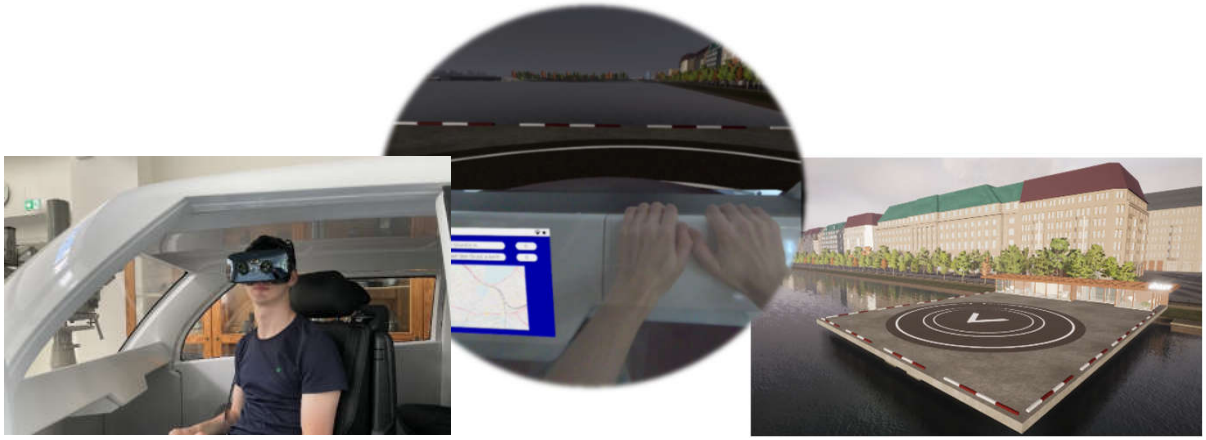
Comfort & Interaction

Work in progress:

- Mixed reality UAM cabin simulator under development
- Real cabin mock-up combined with selected virtual elements, defined near-field elements such as own body remain visible
- Cabin interior design study



Conceptual ideas and first sketches for different seating arrangements

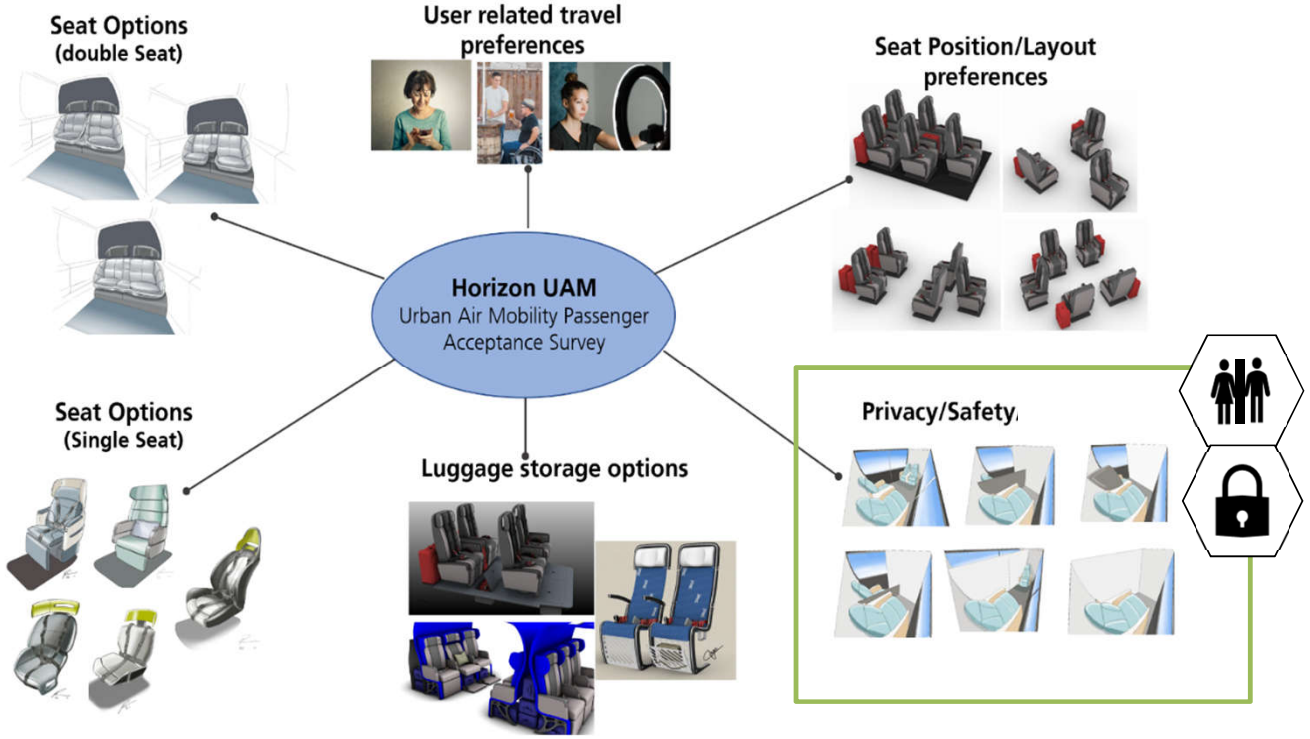


Simulator set-up with cabin mock-up and head-worn mixed reality display, virtual Hamburg scenery

Further reading:

- T. Laudien, J. Ernst, B.I. Schuchardt, Implementing a Customizable Air Taxi Simulator with a Video-See-Through Head-Mounted Display – A Comparison of Different Mixed Reality Approaches DASC 09.2022 (accepted for publication)
- M. Stolz, et. al, See it, hear it, feel it - Using virtual reality to identify risks and benefits associated with drones in urban environments, DICUAM, 03.2022
- I. Moerland-Masic et al., Urban Mobility: Airtaxi Cabin from a Passengers Point of View, Comfort Congress, 09.2021
- M. Stolz et al., A User-Centered Cabin Design Approach to Investigate Peoples Preferences on the Interior Design of Future Air Taxi, DASC, 09.2021

Safety and Privacy in UAM Cabin Design



Volunteers:

- n = 202
- Age: 15 to 79 years
- 56.9 % male,
  42.1 % female,
  0.5 % diverse

- Online focus group study, German population (July-Sept. 2021)
- Evaluation of first cabin design ideas (3D) based on focus group study in 2020
- Main focus on safety, privacy and comfort aspects

Further reading:

- F. Reimer, et. al, Safety & Privacy in Urban Air Mobility – A User Centric Design Approach Providing Insights into People´s Preferences for UAM Cabin Designs, AHFE 2022 (accepted for publication)

Demonstration and Assessment

- Tower simulation for integration of UAM at airports
- Scaled flight demonstrations to show communication, navigation and flight guidance concepts with drones in model city
  - ➢Including assessment of noise app
- Final assessment of chances and risks associated with UAM
- Annual HorizonUAM Symposium

DLR tower simulator

Visualization of the National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt, Germany

Modular model city (scale 1:4) to be erected at test center

Conclusion

- Urban Air Mobility is more than vehicle design!
- Research within HorizonUAM addresses urban air mobility as system-of-systems, including aspects of
  - Vehicle design
  - Infrastructure development
  - Operations and airspace integration
  - Public acceptance

HorizonUAM Symposium 2022

- November 2022, DLR Braunschweig, Germany
- Technical presentations, simulator demonstration, facility tour
- 2 days in-person event
- Further details will follow soon: http://www.horizonuam.dlr.de/

HorizonUAM

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