Agent-based Simulation of Urban Air Mobility

Raoul Rothfeld*, Milos Balac, Dr. Kay Ploetner*, Prof. Dr. Constantinos Antoniou*****

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* Bauhaus Luftfahrt e. V.
** ETH Zurich
*** Technical University of Munich

Table of Contents

Table of Contents

Concept of Urban Air Mobility

Bauhaus Luftfahrt
Neue Wege.

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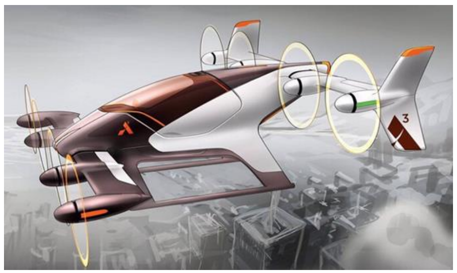
Neue Wege.

Concept of Urban Air Mobility

Bauhaus Luftfahrt
Neue Wege.

>> Variety in vehicle concepts






>> Variety in infrastructure concepts



Table of Contents

UAM Extension for MATSim

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>> ***Co-development between ETH Zurich and Bauhaus Luftfahrt e. V. in cooperation with Technical University of München***

>> ***Three identified main objects to be modelled for UAM:***

- **Properties of UAM vehicles**
  Unique ID, initial location, passenger capacity, cruising and vertical speeds, and maximum range

- **Properties of UAM networks**
  Location and height of nodes, routes including length and flight level, maximum throughput capacity, and maximum free-flowing speed

- **Properties of UAM stations**
  Unique ID, location, and vehicle capacity (e.g. for landing or parking)

UAM Extension Features

Overview

Vehicle	v0.2.3 (current)	
Cruising/vertical speed	✓/✓	No acceleration/deceleration
Initial/dynamic distribution	✓/✓	Simple redistribution based on nearest, first-available veh.
Boarding/VTOL process times	✓/✓	Includes additional procedures (e.g. charging)
Fleet size/mix	✓/✓	No difference in pricing as of yet
Capacity (dimensions)	✓	Simple pooling implementation
Range	✗	Define maximum range

Aerial Network		
Routes/Waypoints	✓/✓	
Flight levels	✓	
Speed restrictions	✓	
Capacity (throughput)	✓	

Infrastructure		
Placement	✓	
Capacity (simultaneous VTOL)	✓	
Capacity (Storage)	✗	Implement landing/parking capacities
Driving access/egress options	✓	Allow for public transport access/egress

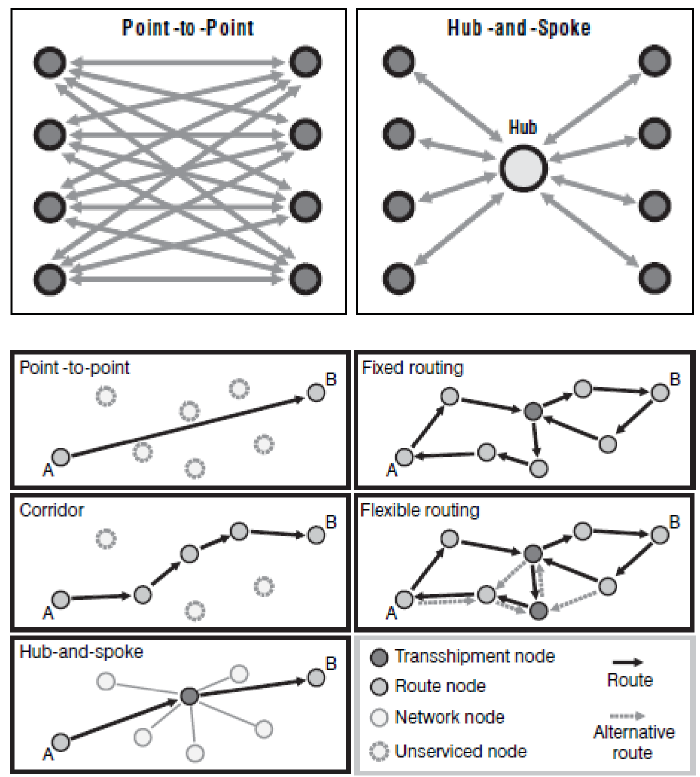
UAM Extension Features

Network Modelling

Vehicle	v0.2.3 (current)
Cruising/vertical speed	✓/✓
Initial/dynamic distribution	✓/✓
Boarding/VTOL process times	✓/✓
Fleet size/mix	✓/✓
Capacity (dimensions)	✓
Range	✗

Aerial Network	
Routes/Waypoints	✓/✓
Flight levels	✓
Speed restrictions	✓
Capacity (throughput)	✓

Infrastructure	
Placement	✓
Capacity (simultaneous VTOL)	✓
Capacity (Storage)	✗
Driving access/egress options	✓

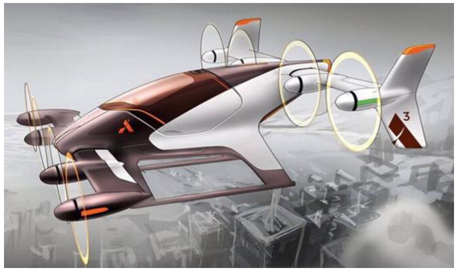


From The Geography of Transport Systems, by Jean-Paul Rodrigue, Claude Comtois, Brian Slack

UAM Extension Features

Vehicle Modelling

Vehicle	v0.2.3 (current)
Cruising/vertical speed	✓/✓
Initial/dynamic distribution	✓/✓
Boarding/VTOL process times	✓/✓
Fleet size/mix	✓/✓
Capacity (dimensions)	✓
Range	✗
Aerial Network	
Routes/Waypoints	✓/✓
Flight levels	✓
Speed restrictions	✓
Capacity (throughput)	✓
Infrastructure	
Placement	✓
Capacity (simultaneous VTOL)	✓
Capacity (Storage)	✗
Driving access/egress options	✓



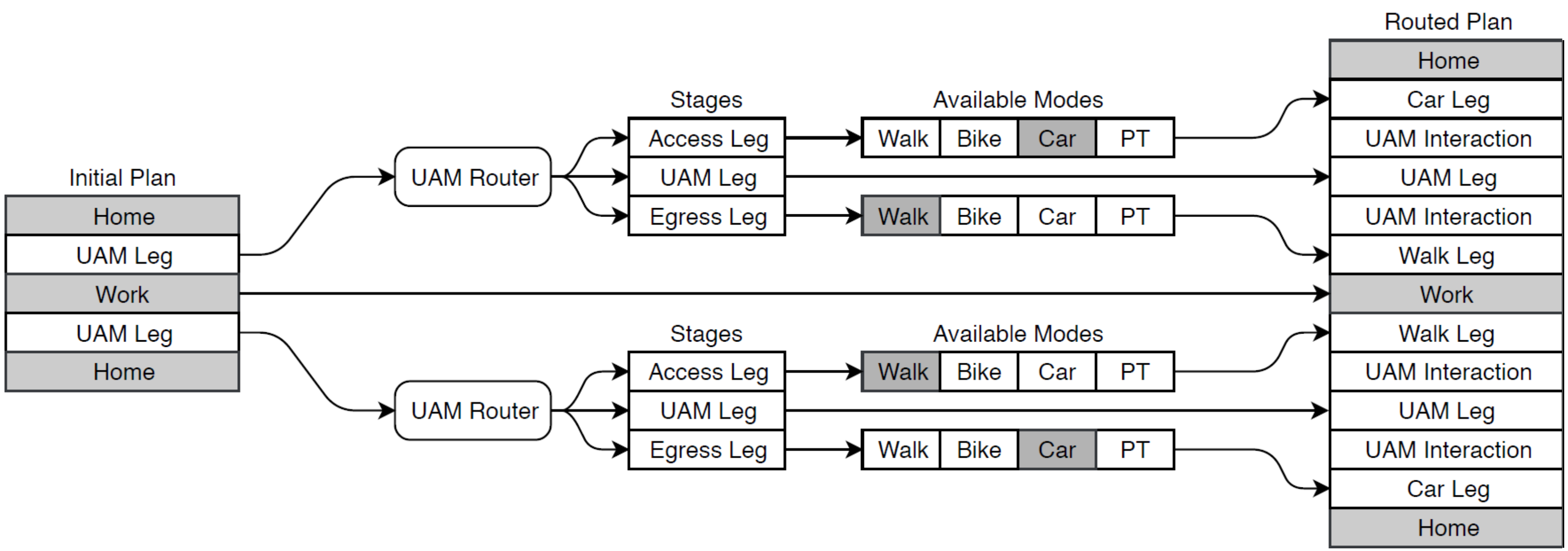
Fast-flying one-seater

Slow-flying one-seater

Fast-flying five-seater

UAM Extension Methodology

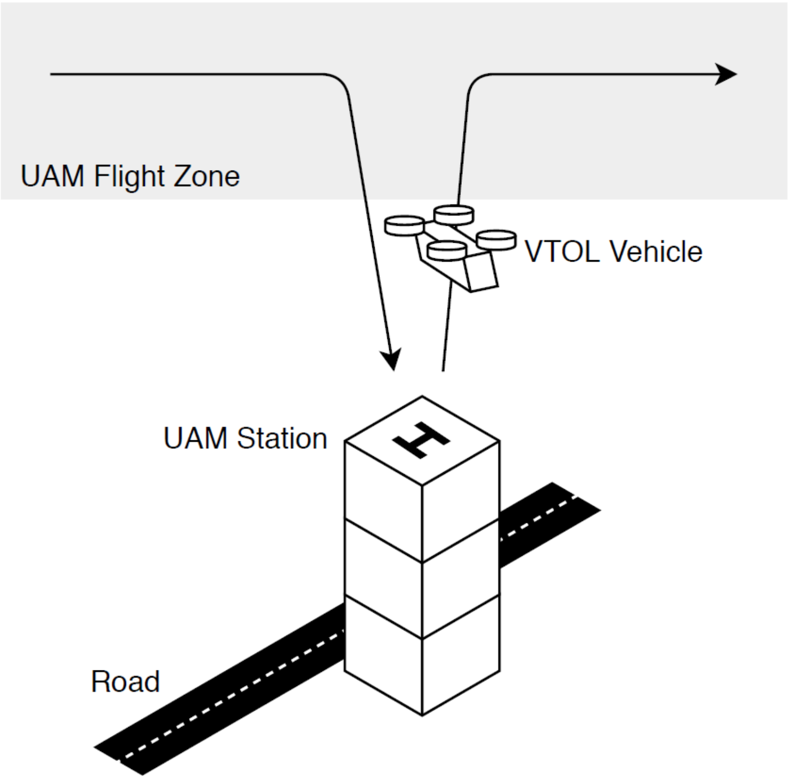
Plan Modification



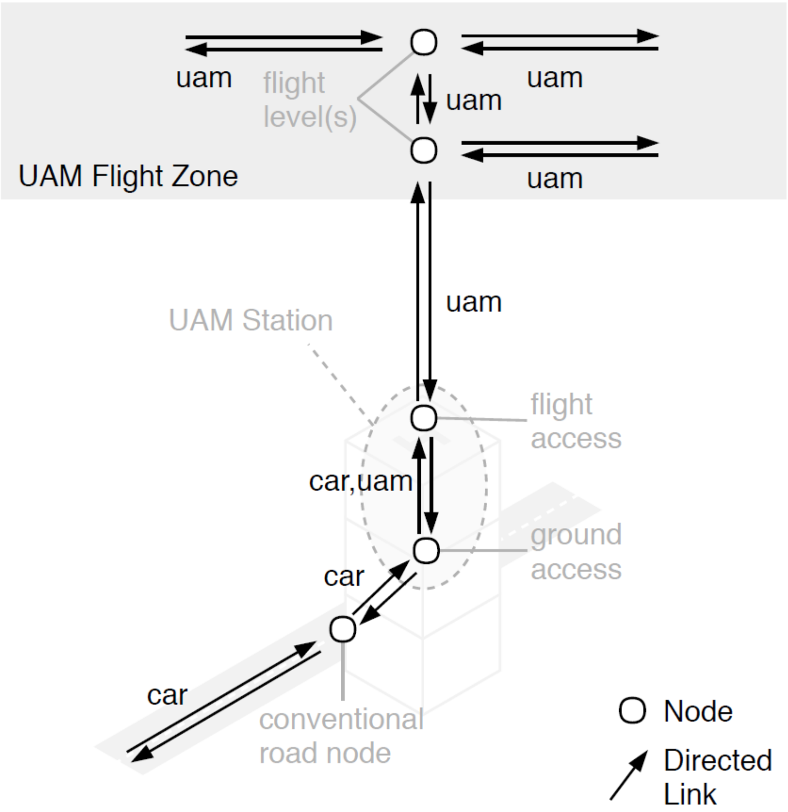
UAM Extension Methodology

Network Encoding

Physical Representation

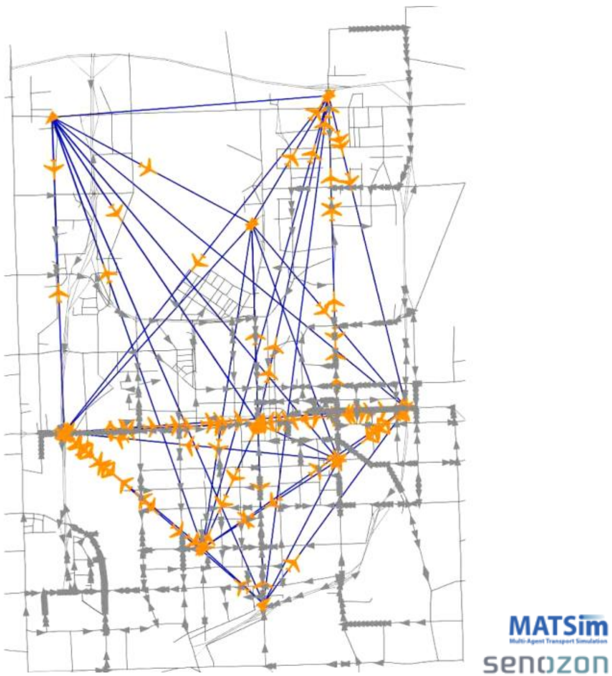


Network Model



UAM Extension Methodology

Network Modeling Test



>> Direct point-to-point network

>> Indirect hub-and-spoke network

- **> Results in longer travel distances and, thus, times**

Table of Contents

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Sioux Falls MATSim Scenario by Hörl, S. (2016)

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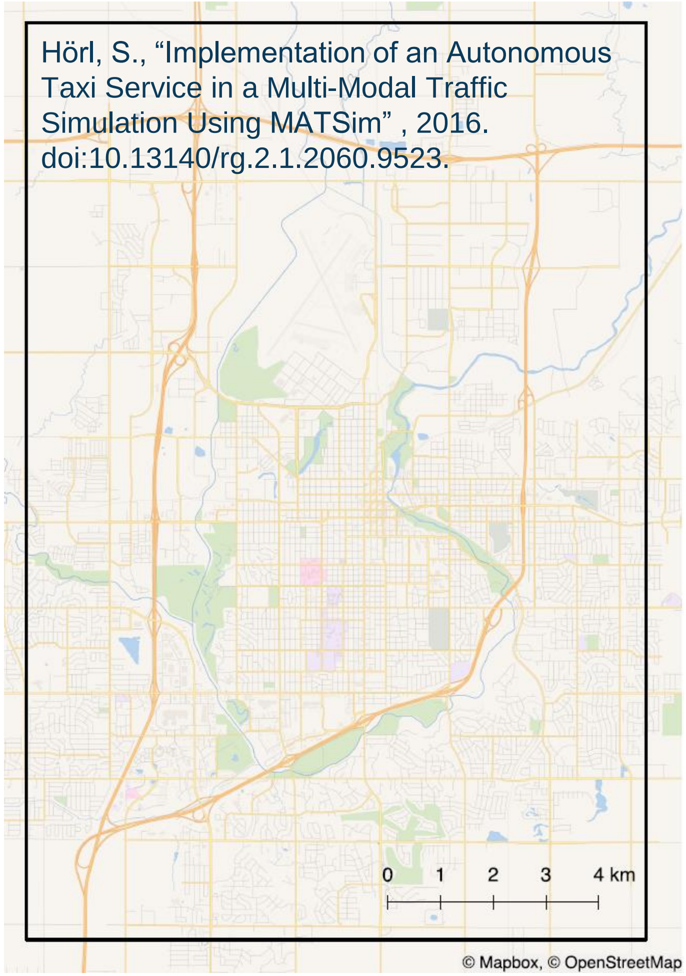
>> Sioux Falls, South Dakota, US

- > Medium sized town (population of 177,000)
- > Often used for transport research

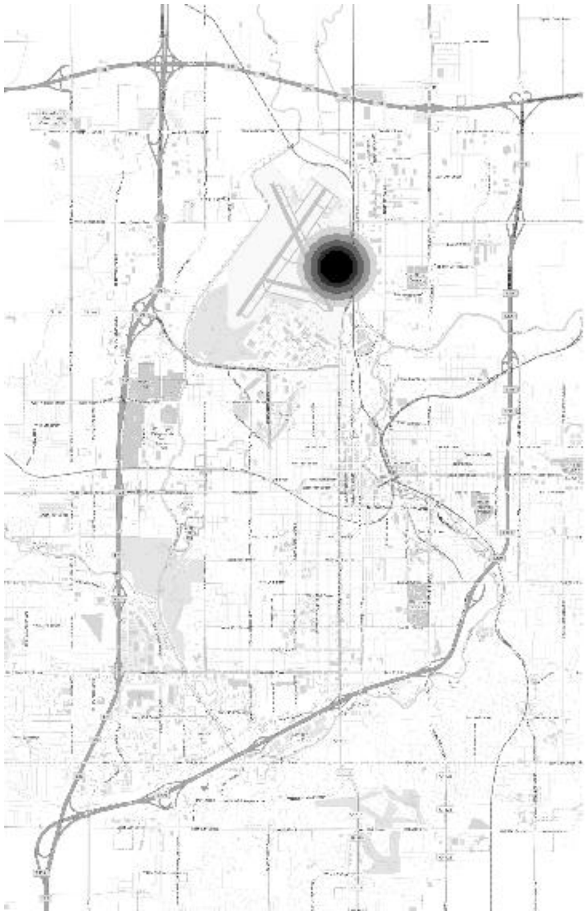
>> MATSim Scenario

- > Refined version created by Hörl, S., building on works of Chakirov, A. and Fourie, P.
- > Intended as a test and prototyping scenario
- > 84,110 agents (48% sample)
- > Car, public transport (5 bus lines), and walking as available transport modes

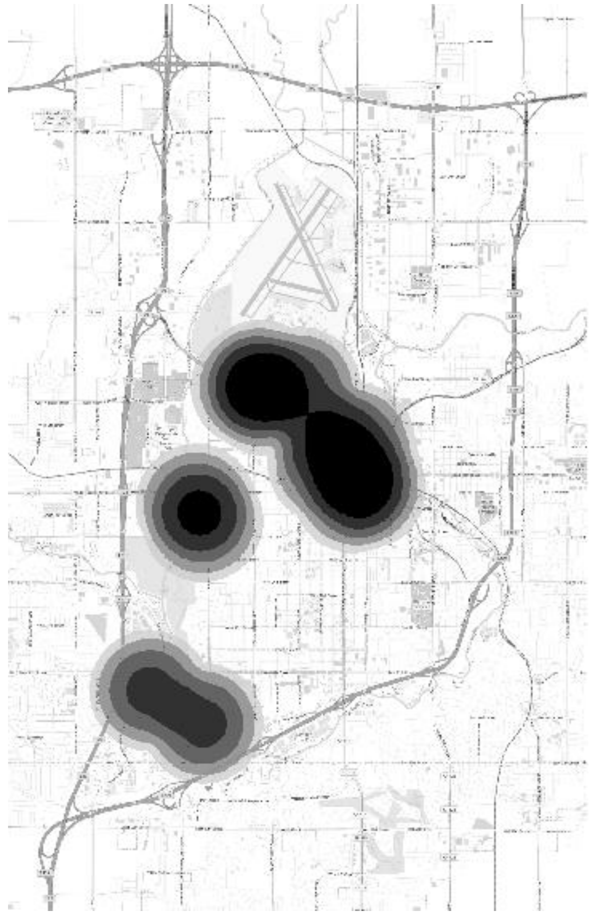


VTOL Infrastructure in Sioux Falls

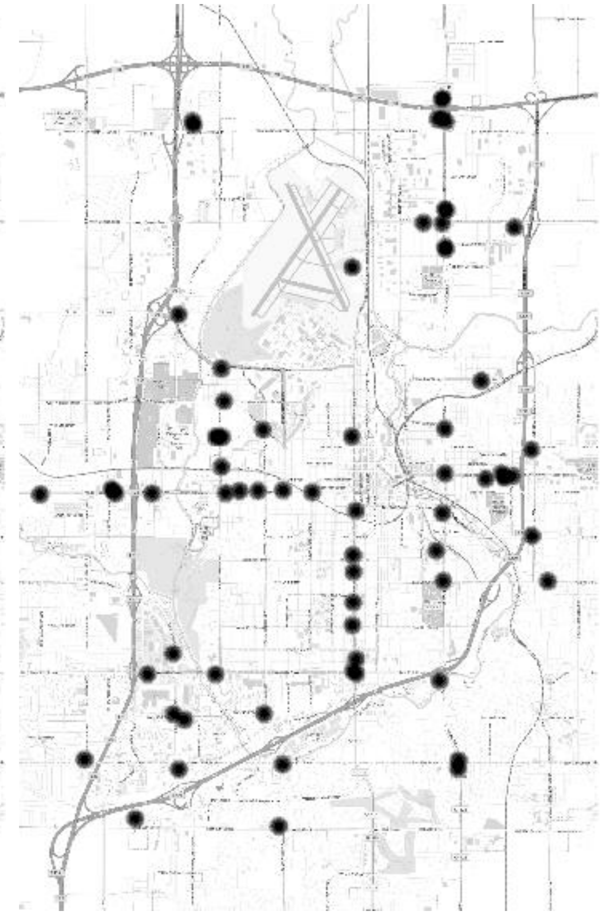
Placement Factors



Transport Nodes



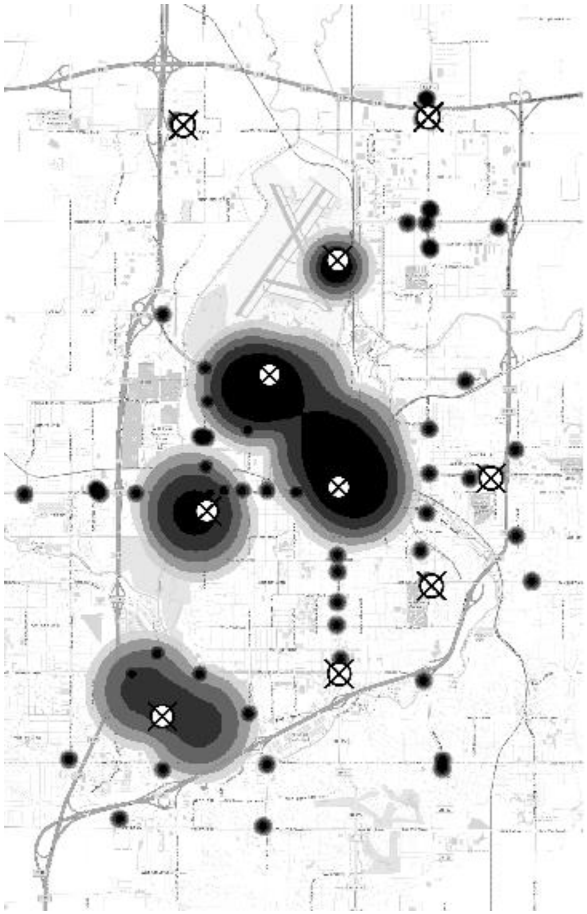
Points of Interest



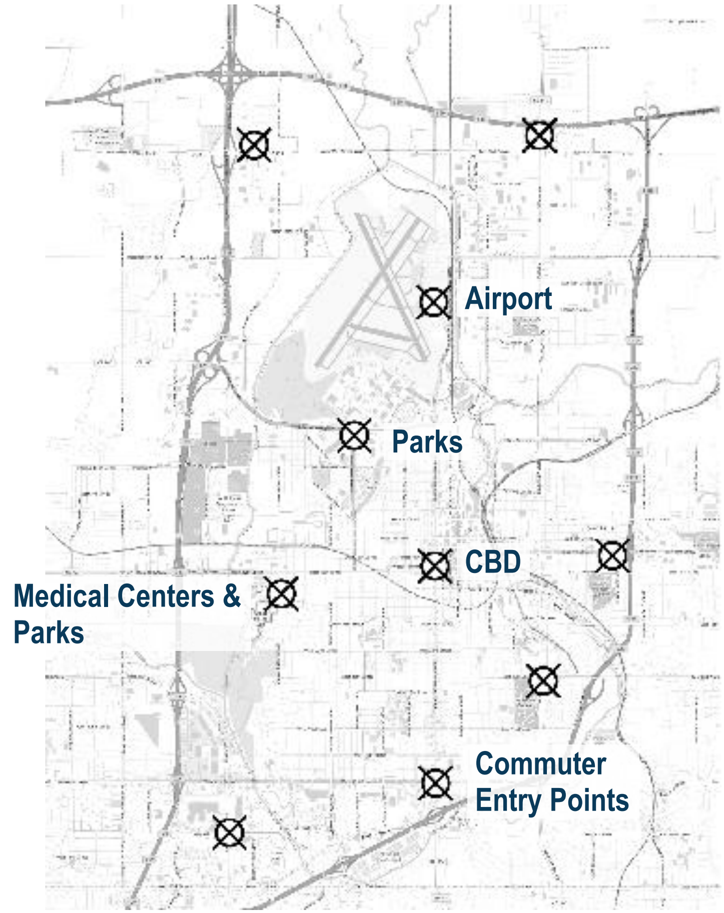
Potential Supply (Existing Helipads)

VTOL Infrastructure in Sioux Falls

Potential UAM Station Placement



Placement Factors superimposed with marked UAM Stations



Placement of UAM Stations in Sioux Falls (Baseline)

UAM in Sioux Falls (Baseline)

Network and Vehicle Placement

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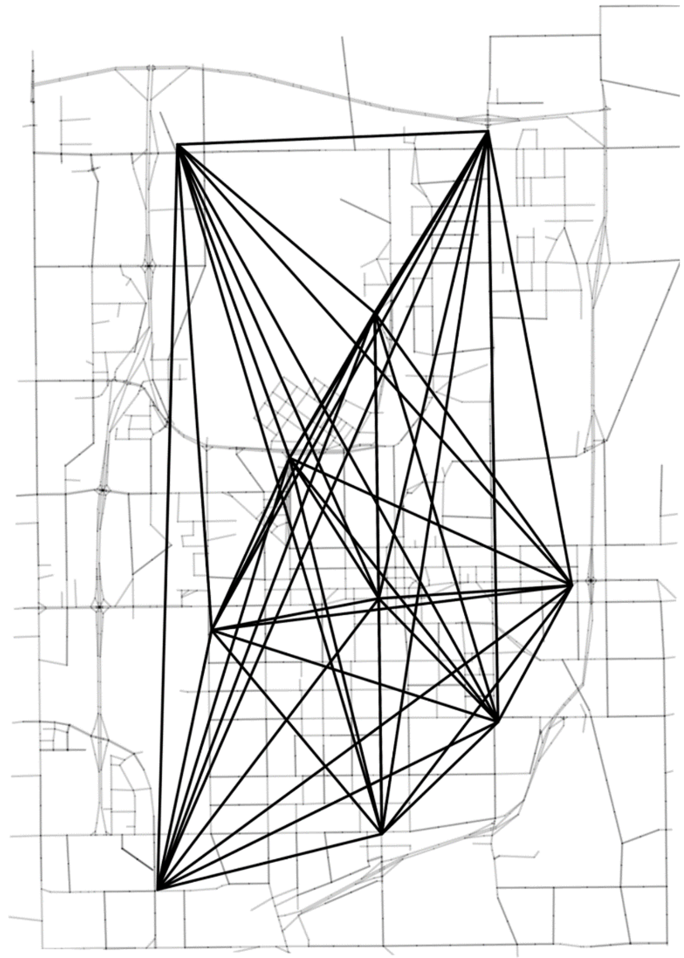
>> Ten distributed UAM stations

>> Stations placed according to points of interest, existing transport nodes, and available heliports

>> Each station starts the simulation with 10 UAM vehicle and is not capacity restricted



UAM in Sioux Falls (Baseline)

Assumption: UAM Transport Cost equals 3x Car Cost

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>> Mode shares:

> At beginning of simulation:	Car: 65%	PT: 28%	Walk: 7%	
> At the end of simulation::	Car: 74%	PT: 18%	Walk: 5%	UAM: 4%

>> Number of daily passengers:

> 6,810 passengers out of population of 84,110 agents

>> Access/egress shares of UAM passengers:

> PT-UAM-Car / Car-UAM-PT	57%
> Walk-UAM-Car / Car-UAM-Walk	17%
> Walk-UAM-PT / PT-UAM-Walk	13%
> Car-UAM-Car	9%
> Walk-UAM-Car	3%
> PT-UAM-PT	<1%

UAM in Sioux Falls (Baseline)

Distribution of Travel/Flight Distances

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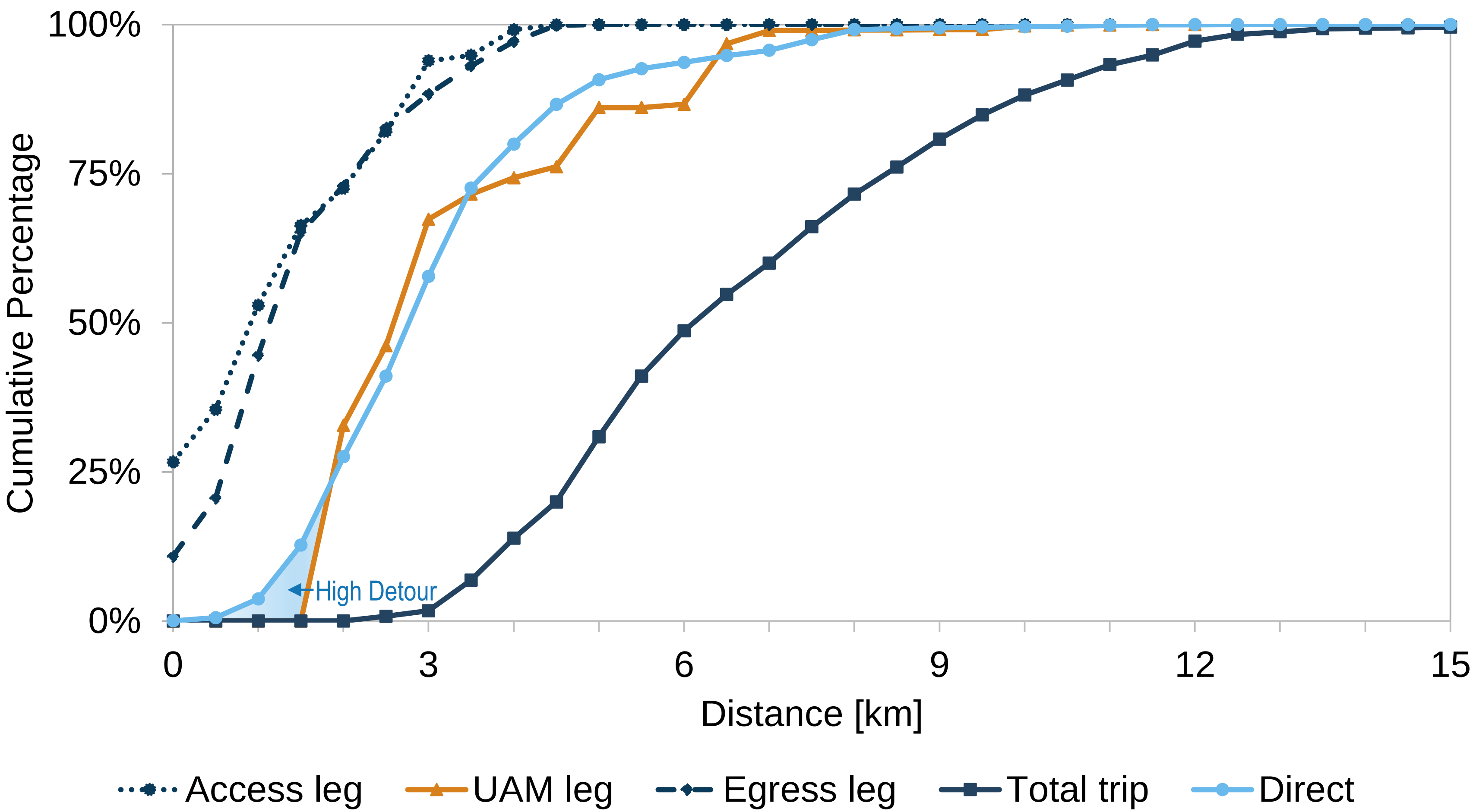

UAM in Sioux Falls (Baseline)

Distribution of Travel/Flight Times

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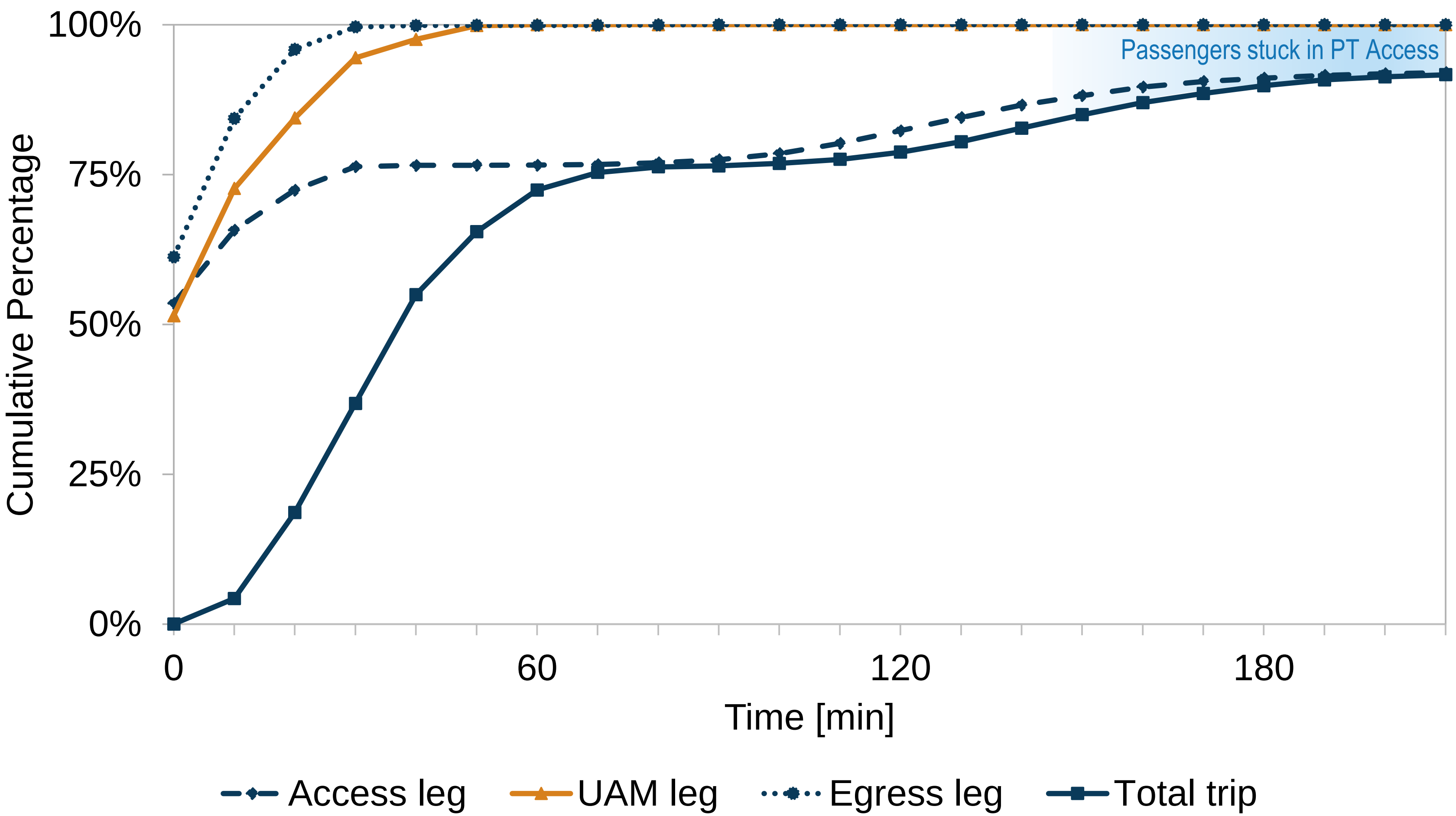

UAM in Sioux Falls (Baseline)

Vehicle Arrival and Departure Wave Pattern

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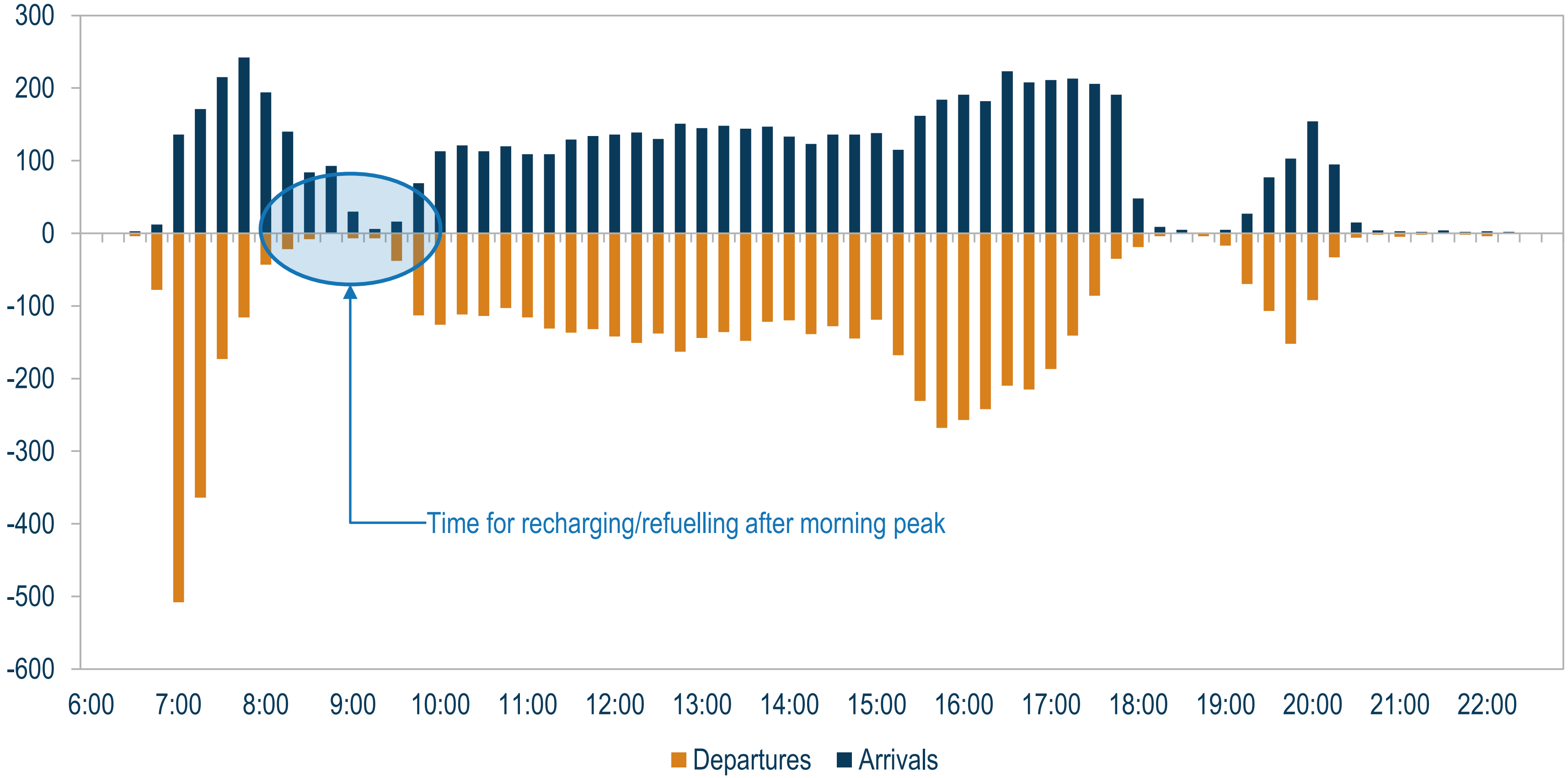
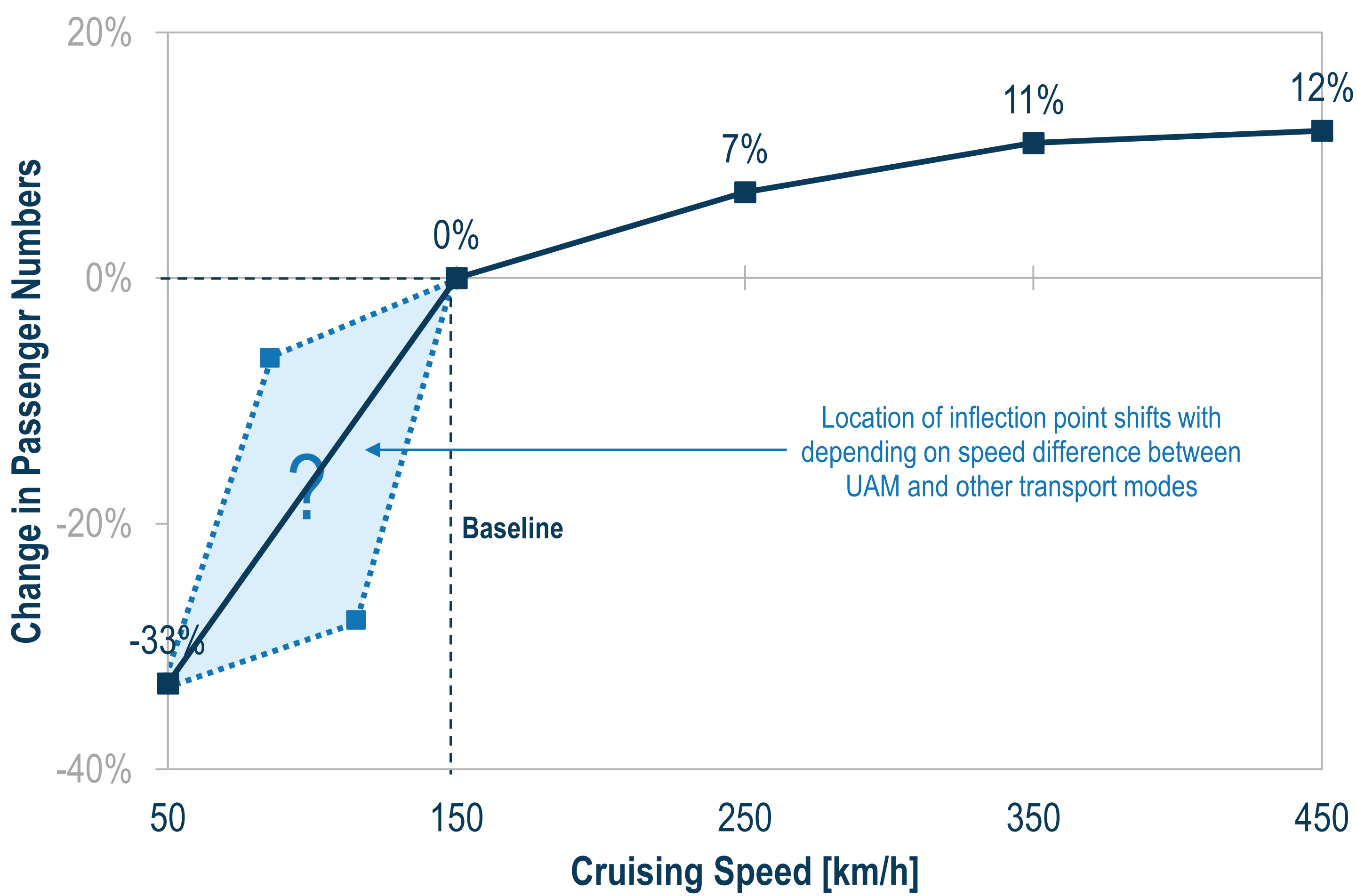
>> Number of UAM departures and arrivals per 15 minutes throughout a day



UAM Cruise Speed Variations in Sioux Falls

Change in Passenger Numbers compared to Baseline Scenario



UAM Process Time Variations in Sioux Falls

Change in Passenger Numbers compared to Baseline Scenario

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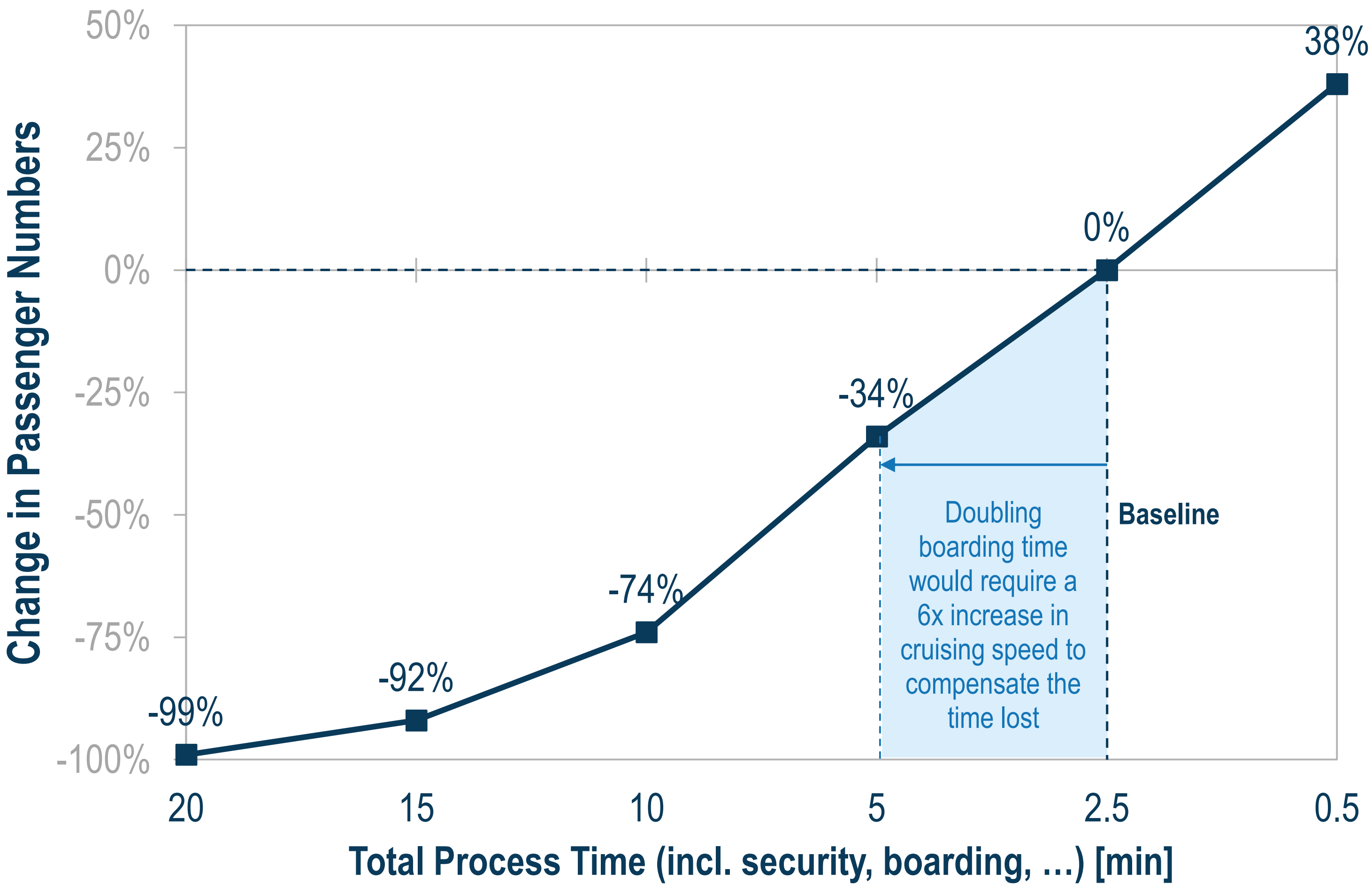
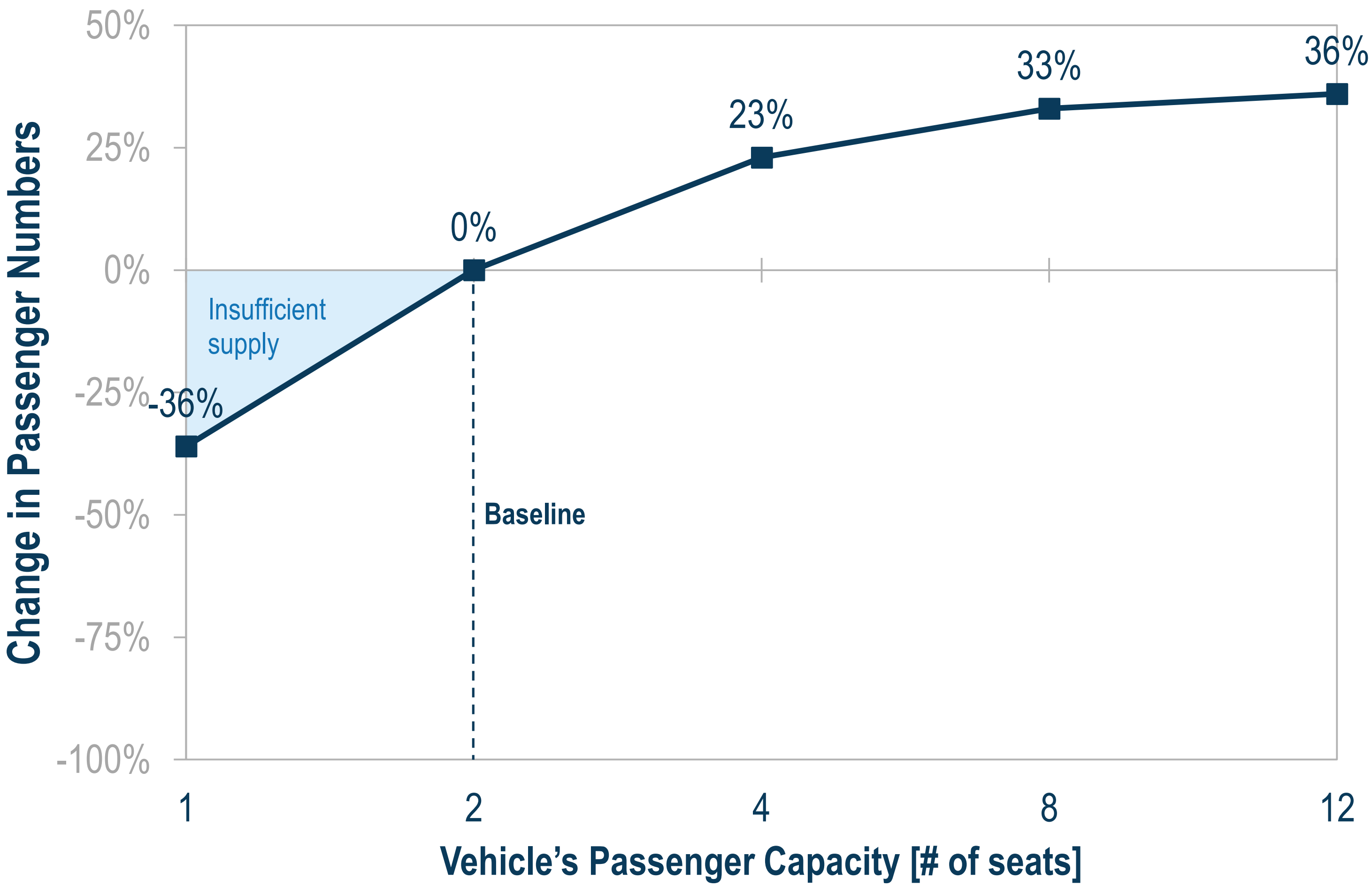


UAM Capacity Variations in Sioux Falls

Change in Passenger Numbers compared to Baseline Scenario



UAM Capacity Variations in Sioux Falls

Capacity Utilization (without Pricing Differences)

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>> Percentages of flights per number of passengers for each capacity scenario:

Passengers	One-seater	Two-seater	Four-seater	Eight-seater	Twelve-seater
1	100.00%	89.79%	80.99%	78.57%	78.10%
2		10.21%	14.56%	13.92%	14.24%
3			3.58%	4.60%	4.44%
4			0.88%	1.81%	1.69%
5				0.76%	0.65%
6				0.29%	0.51%
7				0.04%	0.22%
8				0.00%	0.06%
9					0.06%
10					0.01%
11					0.01%
12					0.00%

! No difference in UAM price for pooled passengers

Table of Contents

Future Enhancement of UAM Extension (1/2)

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>> ***Modeling of charging and refuelling***
UAM vehicles are bound to a certain maximum mission range with need for recharging/refuelling.

>> ***Elaborate vehicle-sharing algorithm***
Combination of various passenger requests with differing origin and destination stations with intermediary stops.

>> ***Elaborate vehicle distribution algorithm***
Implemented of anticipated demand and automatic redistribution of vehicles to stations that are expected to experience vehicle capacity bottlenecks.

Future Enhancement of UAM Extension (2/2)

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>> ***Elaborate station capacities***

More infrastructure parameters are required to reflect the different types and sizes of UAM infrastructure, e.g. passenger throughput, parking capacities for UAM vehicles and cars, different mode-dependent access times.

>> ***Differentiating UAM pricing***

The current ability to define different UAM vehicle types will only be able to have realistic influence on passenger decisions if pricing can be different for each vehicle based, e.g., on the vehicles speed and capacity.

>> ***Application of UAM extension on other MATSim scenarios/cities***

E.g. Munich metropolitan region (maintained by Technical University of Munich)

Conclusion

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- An brief overview of Urban Air Mobility and MATSim, as well as the methodology of the UAM extension and its first application on Sioux Falls have been presented
- The UAM extension has first features to model UAM (such as aerial network definition and UAM vehicle parameters), yet more development is required
- First application on Sioux Falls the sensitivities of mode share based on parameter variations, which highlight, e.g., that for short distances, process times outweigh the importance of cruising speed

Contact

>> Raoul Rothfeld

Bauhaus Luftfahrt e.V.
Willy-Messerschmitt-Strasse 1
82024 Taufkirchen, Germany

Tel.: +49 (0) 89 3 07 48 49 – 14
Raoul.Rothfeld@bauhaus-luftfahrt.net
http://www.bauhaus-luftfahrt.net

>> Milos Balac

ETH Zurich, Institute for Transport Planning and Systems (IVT)
Stefano-Franscini-Platz 5
8093 Zurich, Switzerland

Milos.Balac@ivt.baug.ethz.ch