Analysis of Urban Air Mobility's Transport Performance in Munich Metropolitan Region

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While numerous Personal Air Vehicle (PAV) and electric Vertical Take-off and Landing (eVTOL) vehicle projects are being developed, the potential of their introduction within an urban environment has yet to be understood and applied. Thus, an Urban Air Mobility (UAM) extension for the transport simulation, MATSim, is being utilised on the use case of Munich. The results provide an outlook on the transport performance of various Personal Air Transportation Systems (PATS) concepts.

Nomenclature

DVRP	= Dynamic Vehicle Routing Problem	UAM	= Urban Air Mobility
eVTOL	= electric Vertical Take-off and Landing	VTOL	= Vertical Take-off and Landing
PATS	= Personal Air Transportation System		
PAV	= Personal Air Vehicle		

I. Introduction

Recent developments in electric propulsion and battery technology enable new areas of operation for air vehicles. Quieter operations and shorter mission ranges facilitate air vehicles' urban application. Increasing urbanisation and population growth induce a rising transportation demand. Especially during peak-hours, a high willingness-to-pay for further time-efficient mobility alternatives is to be assumed.

Current developments show a multitude of companies that advance the evolution of personal air vehicles (PAV) as to enable urban air mobility (UAM)[1]. UAM, however, consists of more than the vehicles by themselves, yet requires an operational concept that allows for PAV integration within existing urban transportation systems – a personal air transportation system (PATS). Thus, initial PATS are to be evaluated on their transport performance and operational potential. The analysis will be performed using a multi-agent transport simulation tool MATSim[2].

II. Literature Review

Diverse aspects of UAM are currently being analysed. Uber published a Whitepaper in 2016 stating their view on PATS[3]. Herein, urban air traffic management, noise, pollution, system reliability, and safety are being discussed. NASA published their strategy paper concerning regulatory steps in 2017[4]. Of major importance is the system concept. It is not yet clear which business models will be dominant for PAV introduction and which ownership structures occur. Often, PATS are regarded to be part of on-demand air mobility services with commercially-owned vehicles[5,6]. The business model in this case would be rather similar to that of a car-sharing provider. In contrast, Nneji et al.[7] compare different concepts by distinguishing various ownership options (professional operator or self-operated) and operational models (centralised, decentralised, and self-owned ownership structures).

A major influence on operational PATS models are the PAVs' differing requirements for VTOL infrastructure. The operational requirement has an essential influence on a PAV's option for ownership and operations and, thus, on a potential PATS as a whole. PATS integration approaches – into existing urban transportation systems – will vary substantially depending on the potential need for VTOL infrastructure, as will the system's performance. Besides vehicle speed and capacity, a system's performance, also greatly depends on accessibility and, with that, on, for example, access time, access point distribution, ease and speed of intermodal transfer, and space requirements.

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In order to simulate the introduction of UAM into urban environments, the open-source multi-agent transport simulation tool MATSim[2] will be used, which is jointly developed being by TU Berlin and ETH Zurich.

A synthetic population is generated and represented by agents. Agents perform various activities during the day and generate transport demand by that. MATSim is based on an activity-based approach, which strongly focusses on people's behaviour and the location of their activities. The utility of various activities and their connected disutility, e.g. for travelling to the location of a specific activity, is measured in the scoring function. Agents try to maximise their score by varying their travel behaviours, their activities order, or the activities' starting times until an optimal allocation is reached[8]. MATSim has been used for a broad range of analyses, such as for the simulation of autonomous cars[9], policy evaluation[10], land-use analyses[11], and traffic signal analyses[12]. The most closely related to the application of MATSim for UAM, is an analysis of autonomous taxis by Bischoff and Maciejewski[13,14]. They evaluate the potential introduction of a fully autonomous taxi fleet in Berlin. In order to assign a vehicle to an agent's travel request, they utilized the Dynamic Vehicle Routing Problem (DRVP) contribution[15]. The contribution enables an efficient assignment, as vehicles that are closest to a travel-requesting agent answer the request instead of the first available vehicle. On this basis, a MATSim extension for UAM has been developed[16] and applied on a first test case of Sioux Falls[17]. The application on Munich metropolitan region now presents the continuation of the previously presented research[16, 17] and an enhancement of the UAM simulation methodology.

III. Methodology

As a prototype use case, the city Munich is to be analysed for its potential for PATS integration using the UAM extension[16] for MATSim. The initial analysis will be performed under restricted options for integration and PAV operation as to provide a basis for future, comparative studies and, thus, will be based on assumptions surrounding the PATS environment. For example, it is currently assumed that PAV operation will first be realised providing an on-demand travel model, rather than private operation or public, scheduled transport service models. Further, transport mode choice is simplified to rely solely on agent's value of time, disregarding personal preferences and, possibly, reservations towards an intra-city airborne transport mode.

The initial PATS network design for this Munich use case will be based on VTOL infrastructure scenarios with varying degrees of market penetration (i.e. number, size, and location of VTOL infrastructure). Following a data farming approach, these differentiations in infrastructure availability will be combined with variations in PAV vehicle properties, as described by Shamiyeh[1, 18], and the simulation results contrasted with each other.

IV. Expected Results

Various scenarios of the Munich use case (c.f. Figure 1 and 2) are intended to allow for analyses and first insights on PAV usage in an urban environment in relation to vehicle speed and range, PATS infrastructure distribution and network structure, and different concepts of PAV operation. Of special interest is the overall PATS transport performance in relation to existing transport systems, the airborne system's efficiency regarding PAV usage, and the transport system's sensitivity of variations in PAV characteristics.

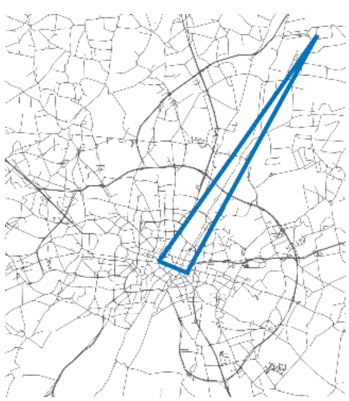

Figure 1. Early, potential UAM network in Munich, connecting the airport to major train stations.

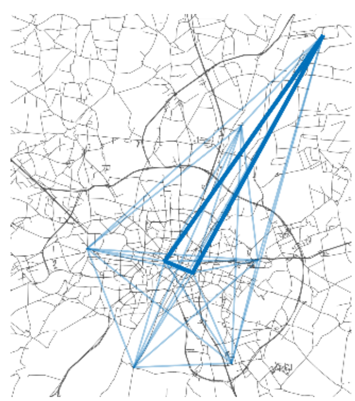

Figure 2. Later, potential UAM network in Munich, connecting multiple destinations.

Additionally, first insights on potential customer groups of urban PATS are to be drawn from analysing the PATS user agent's characteristics and their commonalities. Initial PATS market share estimations will conclude the results and give first indications of the market potential of urban PAV introduction. However, presented results are to be discussed in their validity given the previously mentioned limitations and assumptions on which the simulations are based.

V. Conclusion

The presented results of the Munich use case for the UAM extension prototype will be used to give first recommendations for action for various transport stakeholders, such as cities councils, vehicle manufacturers, and transport operators; and to provide an initial basis for further UAM transport analyses. Further applicability of the presented research and an outlook for future research will conclude this contribution as it is planned to analyse additional cities, implement dynamic mode choice via conducting a stated preference survey, enhance the analysis of VTOL infrastructure placement, and to introduce PAV fleet mix and ride-sharing functionalities.

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