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Competitiveness of on-demand air taxis regarding door-to-door travel time: A race through Europe

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ABSTRACT

We design and implement a door-to-door travel time estimation framework, which aims to analyze the potential competitiveness of on-demand air taxis in Europe when competing with existing transportation modes: car, railway and traditional air transportation. Our grid cell-based framework, opposed to previous studies, allows for fine-grained, high-resolution estimation of travel time lower-bounds between any points in the region of interest. Region-specific results on domination points and competition transitions of all modes are obtained and reported. Our work helps to understand the competitiveness of on-demand air taxis through the lens of door-to-door travel time estimation. keyword: On-demand air mobility; Competition range; Grid-based framework.

1. Introduction

As a result of increasing urbanization, and enforced by the large rise in population, traffic problems become more acute all over the world, particularly with the rise of so-called megacities (Kraas, 2007). These agglomerations of multi-million populations, e.g. London, Beijing, Sao Paolo, Sydney, and Mumbai, face a tremendous amount of transportation demands. The core problem is the same everywhere: Londoners loose an equivalent of 35 working days per year. The traffic chaos in Sao Paolo costs the Brazilian economy at least 30 billion dollars per year. The average commute time for Mumbai residents exceeds a staggering 90 min per day. Moreover, not only the pure waste of time/money should be considered, but also the effect of these stresses on the human body and the environment. Accordingly, given the wide extend of problems with traffic nowadays, it is clear that there is a need for a significant change. Solely increasing capacities of existing transport modes does not lead to the desired goals.

In urban traffic, with less than 500 km distance, the third spatial dimension (= altitude) is largely ignored so far. Traditional air transportation is considered as a valid option for longer distances only (Sun et al., 2017), particularly given the large amount of time required for boarding/de-boarding, security checks, and baggage claims. These additional factors increase the total door-to-door travel time significantly, compared to approx. 700 km/h speed in the air, depending on the distance traveled. Therefore, nowadays it is difficult for air transportation to compete with ground transportation, particularly, given the recent advancement in high-speed rail technology. For instance, now it is possible to travel from Berlin to Munich, a distance of around 650 km using the latest ICE (Inter-City Express) technology within 4 h. The exterior locations of Munich Airport, as well as, to-be-opened Berlin Brandenburg Airport,

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make it increasingly harder for scheduled aircraft to compete with the improved high-speed railway network.

Throughout the last decade, the third dimension, altitude, has risen as a promising solution for satisfying transportation demands on a shorter range. Accordingly, many companies have started to design prototypes, such as the Chinese eHang184, German Lilium, Kitty Hawk, Volocopter, Boeing-Aurora, and Airbus Vahana. On-demand, short–to–medium distance, personalized air vehicles (Schippl et al., 2013; Holmes, 2016) have the potential to radically improve urban and regional mobility, save time in peoples' daily commutes as well as on regional thin haul connections (Kreimeier et al., 2017). A network of small, electric or hybrid-electronic air taxis, which can take off and land at smaller areas, due to their limited size, is going to revolutionize the way we think about transportation. Conducting a conceptual study for the applicability and effectiveness of using on-demand air taxis is computational challenging, mainly due to the conflict of modeling a large urban area of up to 1000 km diameter and the desire to have a high-resolution model that can be used for accurate prediction of transportation mode usage, when introducing on-demand air taxi service.

At RWTH Aachen University in cooperation with the University of Applied Sciences Aachen a regional air taxi is developed, planned entry into service of the Silent Air Taxi is 2024. With four passengers, a range of 500 km can be reached in hybrid-electric mode, with two passengers onboard the range increases to 1200 km. Due to current regulations the vehicle is designed to initially carry a pilot. However, it is equipped with a high level of automation, such that in the medium term safety pilots on the ground will take over control of the fleet of Silent Air Taxis. The Silent Air Taxis have a short take-off and landing capability. Aiming for regional transport the capability for vertical take-off and landing is omitted due to efficiency considerations. Beyond 2030 in order to substantially decrease the door-to-door travel time the Silent Air Taxi will be qualified for take-off and landing on ground based landing systems (Binnebesel, 2013; Rohacs et al., 2014) of 150 m length. This enables the Silent Air Taxi to operate from roof tops of large buildings such as train stations or malls. A lifting body concept allows for a spacious cabin suitable for business travelers and senior passengers. The ducted fans together with an optimized sound quality will guarantee the possibility of 24/7 operation. Ticket prices will be similar to a first class train ride.

The purpose of this research is to design and implement a scalable simulation framework which can be used to assess the impact of on-demand air taxis, such as the Silent Air Taxi described above, on the existing transportation modes. This effort requires to solve several challenges, including data management, accurate modeling of multi-modal transportation infrastructure, and computation hurdles induced by the size of the region of interest. In this study, we develop a door-to-door travel time estimation framework, which is able to compute a lower bound for the travel time between any two points in the region of interest, taking into account four different transportation modes: car, aircraft, railway, and air taxi. Note that subway is not considered as a transportation mode in our current study, because our goal is to estimate travel time without congestion. Subway only has a significant advantage over car transportation in case of congestion/traffic jam. Since our study is concerned with minimum free-flow door-to-door travel time, we take car as a proxy for other public transportation modes, including subway, tram and bus.

We integrate multiple datasets which are available at planet-scale and show how they need to be adapted for estimating travel time boundaries. In detail, we combine transportation data modeled in Openstreetmap (OSM) with the publicly available Open Source Routing Machine (OSRM) and OpenAIP, a dataset on airspace restrictions. Moreover, for determining properties of the regions of interest, such as water/land-coverage and population density, we use the database Gridded Population of the World (GPW). Throughout the study, we model the transportation inside a region of interest by splitting the region into a number of grid cells, which allows for much more fine-grained analysis, compared to traditional inter-city models.

This paper is organized as follows. In Section 2, we introduce and discuss the relevant literature on air taxis. Section 3 describes the methodology for estimating the door-to-door travel time with different transportation modes at a large scale and with fine resolution. We report the results of an experimental evaluation on Europe in Section 4. The paper is concluded with Section 5.

2. Literature review

Several researchers have investigated the emerging business model of on-demand air mobility. Potential market size of thin-haul on-demand air mobility services in Germany was estimated (Kreimeier et al., 2017), with a comprehensive analysis of the entire German population and their linear spatial distances to feasible airfields. Economical assessment of on-demand air mobility with focus on the German market has been conducted (Kreimeier et al., 2016); the willingness-to-pay for the on-demand air mobility was determined, depending on several factors, such as travel speed, distance, convenience, spare time for non-transport related activities, and spontaneity to start a journey. Liu et al. (2017) provided an overview of recent research efforts on personal air vehicles, focusing on the US and Europe research activities. It was found that despite of the dramatic technology innovation, several challenges still remain in the ultimate application of personal air vehicles, especially safety, infrastructure availability and public acceptance.

A few studies analyzed the network topologies of on-demand air taxis. Bonnefoy (2005) evaluated the very light jet air taxi networks in the US, including demand modeling with the gravity model, trip generation based on Monte Carlo simulation, aircraft routing and pilot assignment, as well as unscheduled maintenance events. However, only scenario testing was performed because of lack of air taxi data. The impact of accepting different percentages of passenger-demanded trips and fleet size on the potential profitability of air taxi services was evaluated in Mane and Crossley (2007). A weighted network analysis tool to analyze the on-demand air mobility network was presented (Wawrzyniak et al., 2009), with real-world cargo aircraft movement data within the US central command area of responsibility in the year 2006.

On-demand air taxi service features door-to-door travel patterns, this also indicates more dynamic and complex operations. Moreover, non-revenue-generating trips (repositioning flights) should exist to meet the dynamic demand. Among on-demand aviation services, there are several types of programs: Fraction ownership, time-share, joint ownership and so on Yao et al. (2005). While fraction ownership allows different stakeholder to use aircraft resources for a fraction of time at different levels, it is gradually