Social Sustainable Urban Air Mobility in Europe

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The first step to steer passenger Urban Air Mobility (pUAM) towards the necessity of sustainability is to understand its impact on urban transportation systems. The introduction of pUAM will have a rather negative impact on the social sustainability assessment of European urban mobility systems. The short- to mid-term affordability of pUAM for broad parts of the population cannot be expected without public subsidies. For this engagement, however, local community must first demand clear prospects for added value. Similarly, the overall inclusivity evaluation of urban transportation systems must be expected to decline if planning authorities will not demand certain standards for mobility-impaired groups. Vertiport operation in already developed urban locations might not improve accessibility, however, cross-financed and open access mobility hubs in suburbs and rural areas might include pUAM and thus contribute positively to the access indicator. A high level of satisfaction with pUAM among the public is not expected due to target-group specific business modelling. Last but not least, an impairment of the overall quality of urban public spaces is likely but might be minimised through the allocation of legal competences for urban airspace planning and civil society participation on the local level.

Keywords: passenger UAM ; drones ; urban planning ; acceptance ; vertiports ; affordability ; inclusivity ; satisfaction

1. Introduction

In 2016, official sources estimated around 10,000 electric aircrafts would be in operation for the transportation of passengers in European urban airspaces by 2050 [1]. Today, investments in the respective technologies and regulatory frameworks have led to a more favourable outlook in market research. While first services are expected to launch in 2024, a broader market take-off is projected one year later, and about 160,000 vehicles are predicted to be in commercial operation by 2050 [2]. Meanwhile, efforts are being made to construct a digitalised and highly automated system for urban air traffic management (UTM/U-Space) to allow for the efficient and safe integration of these vehicles into the build environments [3]. From a mobility rationale, it is claimed that passenger Urban Air Mobility (pUAM) will reduce travel time with its integration in intermodal transportation networks, will lighten traffic congestion on the ground due to mode shifting into the air and will ultimately contribute to more sustainable transportation compared to ground-based alternatives due to the use of electric energy sources [4]. Moreover, it is argued that pUAM will not become an exclusive mode-choice for the few, but will soon become affordable, inclusive and accessible to the broader public, satisfying the transportation needs of common people and adding to the overall quality of life in the cities [5].

However, the vision of sustainable urban (air) mobility will not materialise by itself [6]. Initially, a contingency on sustainability effects regarding the use of drones for passenger transportation must be expected. This may include undesirable impacts on travel behaviour, e.g., increasing travel distances and, along with it, a renunciation of more sustainable ground transportation [7]. What is more, the introduction of low-level air traffic in conjunction with necessary transport infrastructure may increase social and welfare disparities among citizens [8]. To anticipate such planning difficulties, an ongoing technology assessment of pUAM becomes highly relevant in (European) transportation research. After all, it forms the precondition for urban planning authorities to make confident decisions on this new technological opportunity in cooperation with industry and communities.

This content analysis provides the audience with a systematic literature research on the social dimensions of sustainable transportation as depicted by the respective European Sustainable Urban Mobility Indicators (SUMI). To apply this framework, pUAM will be considered as a private mobility service complementary to public urban transportation systems. The expected impact of pUAM on the overall affordability, inclusivity and accessibility rating of urban transportation systems will be analysed. Further, the expected impact of pUAM on citizens' perceived satisfaction with the transportation system as well as on the perceived quality of public urban space is investigated. For the analysis, the criteria and aspects underlying the original SUMI are adopted on the specifics of pUAM. To further facilitate the analysis, the conceptual understanding of Functional Urban Areas (FUA) is applied. These comprises densely inhabited cities and their less densely populated commuter catchment area. Consequently, an FUA does not necessarily correspond to the administrative borders of a municipality or region [9]. In Europe, FUAs can be characterised by typically polycentric spatial structures and functionally linked areas, a minimum level of social and economic diversity, the existence of public spaces and greenery and a minimum level of public services, including the provision of public transport [10].

2. Social Sustainability in Urban (Air) Transportation

In respect to the long tradition of transportation research, sustainable mobility is a relatively young concept which took off with the 1992 Green Paper of the European Commission "The Impact of Transport on the Environment: A Community strategy for "sustainable Mobility" [11]. The document acknowledged an increasingly problematic relationship between transport's positive effects on economic welfare and its negative environmental impacts. From there onwards, research and policy foci, methodological approaches as well as research questions have undergone substantial changes [12]. The ongoing observations regarding the impact of transportation on economy and society as well as their inter-relatedness have led to more integrated, interdisciplinary perspectives.

To describe this complexity and to illustrate trade-offs or synergies in the context of political decisions-making and urban planning, a large number of researchers refer to the triad of ecological, economic and social pillars of sustainable mobility (e.g., [13][14][15]). While the economic pillar emphasises the role of mobility to ensure resource efficient production and development, the ambition of environmentally sustainable mobility contributes to the preservation of the climate, the conservation of non-renewable resources, the protection of biodiversity and the abatement of air, water and ground pollution. The social pillar ensures that mobility contributes to community cohesion by supporting equity, participation, health and security in society [16]. Socially sustainable mobility systems would therefore ensure that everyone is able to satisfy his or her transportation needs to engage in social and economic life on an equal basis. Therefore, the affordability of transportation for everyone is highly relevant, as well as its spatial accessibility and its inclusivity, e.g., for mobility-impaired groups [17].

Sustainable Urban Mobility Plans (SUMPs) offer the possibility to anchor these long-term goals for integrated freight and passenger transport, increased quality of urban life and environmental protection in transportation planning processes. SUMPs have been proposed by the European Commission as part of the "Action Plan on Urban Mobility" in 2009. In 2014, corresponding community guidelines have been approved by the European Union General Directorate for Mobility and Transport. Since 2019, in a revised edition, these guidelines constitute a fundamental methodological reference for municipal stakeholder initiatives to foster sustainable urban mobility in Europe and abroad [16]. SUMPs envisage to: (1) define a future vision and milestones for; (2) assess the current performance of; (3) implement measures in; and (4) re-evaluate an urban transportation system [18].

Sustainable Urban Mobility Indicators (SUMI) thereby reflect the conceptual understanding of sustainable urban transport in European policy and are the methodology to assess the actual impact of sustainable urban mobility planning practices described above. The set of these altogether 19 indicators is used to: (1) describe the performance of an overall urban transportation system or a certain aspect in a standardised form; (2) identify strengths and weaknesses in respect to certain policy targets or indicator thresholds; as well as to (3) assess the effectiveness of implemented policies and practices, e.g., by analysing a shift before and after the introduction of new means of transportation. The social dimension of sustainable urban transportation is reflected within five indicators, which measure the affordability of public transport for the poorest group, the inclusivity of public transport for mobility-impaired groups, the accessibility to mobility services for citizens, the satisfaction with public transport as well as with the quality of public spaces [18][19].

3. Related Work

3.1. Affordability of pUAM

Studies attempting to estimate the price of pUAM suggest it to be below the per-kilometre price of existing helicopter point-to-point services but also far above the price of traditional taxi services [20][21]. More precise and comparable examples have been found only for eVTOLs with the capacity for three passengers, including one pilot. Based on a calculation made in the U.S. context, the median price per passenger and mile was found to be USD 7 net [22], corresponding to approximately EUR 3.78 per kilometre in 2021. Consequently, a 70 km flight from San Francisco to San Jose would cost around EUR 265 per passenger. A comparable study on the use of pUAM to supplement public transportation in the metropolitan FUA of Munich, Germany anticipates a price per passenger and kilometre of EUR 4.94. The charge for a 70-kilometre regional flight from Munich to the city of Ingolstadt would therefore be at least EUR 346 per passenger. For shorter inner-city trips or suburban connections, the study proposes additional basic fares up to EUR 20, making a 10-kilometre trip cost around EUR 70 per passenger [23]. The realism of these price calculations is in respect to the multitude of deduced and sometimes daring assumptions, e.g., regarding public funding of pUAM infrastructure, is hard to assess. Both examples underline, however, that early pUAM cannot compete with common modes of urban transportation (a monthly ticket for the extended Munich region Q1 2022 costs around EUR 230), let alone be affordable for regular commuting by broader parts of European society.

3.2. Inclusivity of pUAM for Mobility-Impaired Groups

The only reference found that specifically analyses the requirements of mobility-impaired groups for the design of pUAM services is published by NASA as a technical memorandum. It includes design considerations for the accessibility of ground infrastructure, vehicle access and cabin layout, consideration for in-flight operation and emergency response, as well as for the accessibility of digitally mediated information, ordering, booking and payment processes. The researchers emphasises the relevance of including the needs of mobility-impaired groups from the earliest stages onwards into the design and development process “of the overall system-of-systems network inherent in the UAM concept” to create path dependencies in favour of an inclusive transportation service [24] (p. 6).

If and to what extent current private sector development is anticipating this appraisal cannot be assessed from the literature. However, researchers in the field of traditional aviation stress that handling passengers with special needs is posing additional cost that affects profitability and competition between airlines. This is particularly the case when closely timed operational processes are ‘disrupted’, or when customers are entitled free of charge to be guided by assistance personnel or to cargo space for mobility aids and medical equipment [25]. Accordingly, for pUAM services, trade-offs between the degree of inclusivity that could be offered and the financial requirements for infrastructure, vehicles and adopted operational procedures needed to realise it must be acknowledged.

In future, legal obligations might assist in shaping the inclusivity of pUAM services for mobility-impaired groups. For example, Straubinger et al. discuss pUAM as part of public transportation in Germany, implying an applicability of the National Public Transport Act [26]. This regulation obliges MaaS providers such as taxi, ride hailing or ride pooling companies with a fleet size from 20 vehicles to ensure at least 5% of their fleet to be accessible for disabled persons. Drawing this analogy, pUAM providers may become committed to certain inclusivity standards for their vehicles and infrastructure as a prerequisite for an operational approval from the licensing authority in the respective territory. Besides national level jurisdiction, European legislation may as well demand inclusivity standards for pUAM in future, as is currently in place for international aviation carriers, ships as well as rail transportation [27][28]. Finally, missing inclusivity standards might impact the overall customer satisfaction and public perception of pUAM negatively, hence pressuring manufactures and operations to adopt [29].

3.3. Access to pUAM Services

The impact of pUAM on the accessibility rating of urban public transportation systems in Europe will largely depend on the layout of vertiport networks, its reachability for customers and its performance.

4.3.1. Vertiport Placement

Regarding vertiport placement, studies apply demand-driven approaches, aiming to identify connections that will create reliable revenue in early market operation. The spatial distribution of vertiports is thereby dependent on the expectable number of trips between catchment areas in a city and the likelihood that people for these trips will choose pUAM over existing alternatives (cf. [28]). Primarily, high demand stems from agglomerations of commuters traveling between transportation hubs, residential and business districts of a metropolitan area [30]. As those are characterised by a certain density of transport infrastructure and saturation with public/private transport services, pUAM will likely represent an additional, potentially more time efficient mobility offer rather than filling accessibility gaps in urban transportation systems. While it would be through the commissioning and operation of vertiports in less connected neighbourhoods and remote suburbs that the establishment of pUAM would increase the transport accessibility rating in the respective areas, low demand counteracts such line of thoughts [31].

3.3.2. Reachability of Vertiports

The reachability of vertiports, e.g., in walking distance (a reasonable walking distance is quoted to be up to 2 miles/3.2 km [21]) presents a relevant factor for pUAM services to realise overall travel time savings compared to competing means of ground transportation [32]. However, the extent to which good reachability will be archived in complex urban environments is difficult to foresee. In the current state of research, vertiports are computed rather ideally into predefined catchment areas while planning vertiports is suggested to prove more challenging in real world scenarios [33][34][35][36].

As one particular planning constraint, the available space may prove a barrier. In regard to this, EASA already published technical design specifics for vertiports on the ground as well as on heights, such as business buildings and car parks for congested urban areas. Thereby, the vehicle touchdown and take-off area (TLOF) is covered by a rectangular funnel that widens towards the top. No obstacles may protrude into this volume for safety reasons. In the considered reference model (Volume Type 1), the height of the funnel is around 30 metres and the take-off and landing area is two times the diameter of the smallest circle enclosing the respective VTOL aircraft, which may be about 400 m² in size [37]. Thus, even when adding necessary facilities for passenger handling, the already iconic renderings of small landing pads on high-rise rooftops for a pUAM touch-and-go configuration in inner-city districts appears feasible. However, with the capacity for one vehicle only, these pads are significantly limited in their customer throughput rates. When anticipating the time for eVTOL landing and egress of three passengers, respectively for the boarding of three passengers and eVTOL departure with five minutes (process times are derived from Preis and Hornung [38]) each, 36 persons per hour could be serviced in scheduled operation under the most idealistic conditions. In mobility-on-demand operation, whereby more people want to land at inner-city vertiports in the morning or take off after work, higher costs, negative environmental impacts and, after all, operational inefficiencies are expectable from a repositioning of empty eVTOLs. Aiming for higher performance, Rimjha and Trani assume a size of around 8000 m^2 for a vertiport with parking stalls for eight eVTOLs, the necessary taxiing areas and one TLOF [39]. This equals to the size of a football field. Thus, when guaranteeing certain baseline capacities, the search for well-located infrastructure areas within walking distance can be expected to become significantly more difficult.

In addition to the availability and the financial feasibility of such spaces, the localisation and operation of vertiports is expected to become influenced by safety regulations as well as regulations for the protection of residents and the environment from harmful impact [40]. Similar to airport planning, research suggests that a reconciliation with public and residential interests, e.g., regarding urban fauna or protection from emissions, may impact administrative decisions on vertiport sizing and operations [41]. In this respect, residential acceptance becomes another relevant dimension of consideration. Besides externalities on neighbours from noise, also visual pollution, security concerns, privacy or increased traffic and congestions in the surrounding area may foster a rejection of vertiports in economically attractive catchment areas [42] p. 88. Factoring in these aspects, researchers point out that operational requirements of vertiports in interchange to questions of residential acceptance could be lower on private industrial and commercially used spaces [26]. What is more, participatory planning approaches involving residents are suggested to help mitigate social vertiport planning obstacles, supporting the placement of vertiports in closer proximity to its potential beneficiaries [43].

3.3.3. Vertiport Frequencies

Last, to understand the impact of pUAM on the overall accessibility rate of an urban transportation system is the frequency with which vertiports and thus customers will be served by eVTOLs. Thereby, a vertiport must always be comprehended as a system bound to the capacities of its surrounding urban airspace and, hence, the U-Space management efficiency. However, the throughput capacity rate of a vertiport itself is primarily affected by (a) the vehicle specifics, including time for vertiport approach and departure, (b) the available size of the vertiport impacting the organising of ground operation and, of course, (c) turnaround times of the vehicles involving passenger handling [44]. The researchers Preis and Hornung contribute to a better understanding on how these operational parameters affect the average wait time for pUAM passengers. Using an agent-based simulation, the researchers conduct a sensitivity analysis that includes varying parameters regarding passenger demand, vertiport layout (pads, gates and stands) and processing times for eVTOLs and passengers. The results suggest that while each vertiport can handle a certain amount of constant demand with which low passenger wait times and reliable performance are conceivable, temporal peaks in demand have a significant impact on delay times (this may be less consequential for pUAM in scheduled operation and fixed ticket contingent, but significant for future on-demand operation and asymmetric arrival and departure requests). Much stronger, however, because growth is exponential after a certain tipping point, is the impact of increased processing time for vehicles and customers as well as a decreased availability of landing pads and gates on the average passenger delay. Hence, unexpected disruptions in vertiport operation or sudden airspace restrictions due to weather change or emergency operations may result in major delays for passengers [38].

3.4. Satisfaction with pUAM

As no large-scale pUAM services are available yet, the actual customer satisfaction cannot be assessed. However, studies on the willingness to hire or pay for pUAM once services are available can contribute to a more detailed understanding of the prospective satisfaction with pUAM. In summary, the general willingness to use air taxiing is low. For example, a population representative survey with 1000 respondents from Germany finds that only 18 per cent are open to use air taxis for their individual mobility [45] p. 6. However, Winter et al. show that the willingness to fly in an eVTOL increases the more this action is perceived as useful in a given situation [46] and al Haddad et al. show that the willingness to use pUAM increases the more the respondents associate the use of this service with a reduction in travel time [47]. Consequently, it is more comprehensible that a representative study commissioned by EASA with 3690 participants from six European metropolises concludes that, on average, 49 percent of respondents would at least try out and pay more for an air taxi under the condition that the given trip would be done in half the time compared to using a road taxi service [42] p. 62. Thus, the usefulness and advantageousness over its alternatives will be a decisive factor for customer satisfaction with pUAM.

3.4.1. Perceived Safety

In respect to the perceived safety, the before mentioned surveys from EASA shows that safety is rated the most prevailing concern for respondents from Europe [42] p. 73 while the respective survey from Germany shows that 53% of respondents disagree on the question if they would consider passenger transport with air taxis to be safe [45] p. 9. For the prospective satisfaction with pUAM services, this may be consequential. Lim et al. argue that a high safety perception and trust in eVTOLs will be most important for a positive user evaluation, especially for the initial stages of pUAM (priorities are expected to change in favor of service orientation once pUAM services proof their reliability) [48]. Adding to these results, statistical research suggest that respondents' feelings of safety towards eVTOLs strongly depend on how it is piloted. Chancey and Politowicz show in their study design that the willingness to use remotely piloted pUAM services is lower compared to services with an on-board pilot, as the latter is trusted more [49]. Similar results can be found regarding the future potential for fully automated [47] or autonomous [46] eVTOL operation in passenger transportation respectively. Researchers indicate that the willingness to use and pay for pUAM decreases the lower the level of respondents' understanding towards the technology responsible for flight control [46][47]. Comparable results have been suggested in relation to automated long-haul aircrafts [50]. Thus, a safety perception towards the technology is somewhat a precondition to feel satisfied with pUAM. However, research suggests that trust levels or safety perceptions are significantly influenced by certain demographics. For example, it is suggested that younger persons have a higher affinity to vehicle automation while older persons have greater safety concerns. Further, it is suggested that women would simply feel more comfortable boarding an eVTOL with a pilot [51] or at least some sort of security monitoring in the aircraft cabin, respectively [47].

3.4.2. Perceived Affordability

Regarding the perceived affordability, studies aim to forecast not the actual cost of using a service for the individual (see chapter 4.1), but the threshold above which average customers become unsatisfied with the pricing scheme and unwilling to pay for the transport mode (cf. [52]). In alliance with prevailing transport planning approaches, this willingness to pay is conceptualised as a customer's trade-off between the value of travel time savings and financial cost [53]. Building on this presumption, Balac et al. included the option of Air Taxis in a mode choice simulation with agents representing 10% of the population from the canton of Zurich, Switzerland. They researched the impact of varying passenger handling times as well as travel speeds and costs. According to their research on the sample, the willingness to pay decreases significantly above a base cost of CHF 6 and a cost per kilometre above CHF 1.8 [54] (equalising to around EUR 1.8 in Q1 2022). For the USA, Goyal et al. modelled the sensitivity of customer demand to changes in the flight price for 10,000 randomly generated air taxi missions in ten metropolitan areas each and found that highest revenue in trade-off to customers' decreasing willingness to pay would be achieved at USD 2.50–2.85 per mile [22] (equalising to around EUR 1.5 to 1.7 per kilometre in Q1 2022). Concluding this, the price level up to which a broad customer satisfaction with pUAM services is suggested is more than 50% below prices to be expected from current estimations (cf. [22][23]). In addition, while it is commendable in terms of social sustainability that broad segments of the population were targeted in the respective research for acceptable pUAM pricing, Ahmed et al. emphasise the circumstance that the willingness to pay and therefore the satisfaction with service prices is highly dependent on the individual characteristics. For example, persons with an annual household income over USD 100,000 are expected to be more willing to pay up to USD 6.5 per mile for pUAM services [51], closely reaching the realistic cost estimation made by Goyal et al. [22].

3.4.3. Perceived Service Reliability

As research shows, the perceived service reliability, e.g., on-time performance [47] and low performance risks [55] are significant for the adoption of air taxis and the willingness to use all-electric passenger planes respectively. The latter decreases the more respondents are concerned about the risk of not being able to complete their journey satisfactorily, that problems during the journey cause cognitive stress, and/or that money will be lost due to any concomitant circumstances [55]. Thus, unforeseen operational constraints in connection with pUAM would likely impact the perception of the reliability of pUAM significantly and consequently, passenger satisfaction with the service. As shown in the previous chapter, unexpected disruptions in vertiport operation may result in such unwanted events and long passengers waiting. Additionally, airspace restrictions may prevent flights at short notice, e.g., due to bad weather or due to congestion from other urban air space users [38].

3.4.4. Perceived Easiness to Use

Last but not least, the perceived easiness to use pUAM receives consideration in research to improve customer acceptance and satisfaction. In the logic of the adopted indicator, highest customer satisfaction can be assumed when an easy booking and payment process is in place, vertiports can be accessed comfortably, waiting times are appropriate and overall service quality is high [30][47][48]. Regarding the booking process, the integration of pUAM into the MaaS environment is anticipated in most related research, which will allow booking and paying for the complete travel chain using a digital platform [7]. Travel can thus be expected to be comfortable for digital natives. Research on acceptable wait times for pUAM was not found. However, as scheduled pUAM operation is anticipated and time saving is suggested to be a primary decision factor for customers, a threshold for acceptable wait time should be reached where it will become worthwhile for customers to choose another mode of transport in a given booking. As outlined before, these wait times will be impacted foremost by vertiport operations and airspace access [56]. Regarding service quality, Edwards and Price in their research for NASA on eVTOL Passenger Acceptance highlight several issues that could strongly impact customer satisfaction. To name a few, feelings of anxiety could arise from in-fight turbulence and gust responses; vehicle noise may cause discomfort; or outside-visuals may cause intimidation. Emphasising the yet small body of research on these aspects, the researchers request further engagement in this field to ensure “that the passenger's first ride is not also their last” [29] p. 3.

3.5. Impact of pUAM on the Quality of Public Spaces

Similar to the evaluation of customer satisfaction, hints of a changing perception towards public spaces through pUAM can only be sustained through survey data and statistical model approaches. Regarding survey data, the before mentioned EASA study anticipates various impacts of vertiports as necessary ground infrastructure on the perceived quality of public spaces by the population. Respondents that were asked to rank their most relevant concerns related to close-by vertiports in their surrounding area rated noise (48%) and safety concerns (41%) most often. Furthermore, concerns regarding visual pollution (32%), increased inbound and outbound traffic (29%) and the occupation of spaces better used for living or recreation (28%) ranked high in concerns as well [42] p. 88. Regarding the impact of air traffic in the urban sky, in the before mentioned Sky Limits survey from Germany, 43% of respondents thought that air taxis would make urban spaces less pleasant to live in while just 22% of respondents were certain that passenger transport with air taxis would have a positive effect on the quality of life in cities. Asked about a future in which many people were to use air taxis, 61% of respondents rated it very or quite bad if air taxis would block the currently unobstructed view of the sky [45] p. 8, 14.

By creating a sample with 800 respondents from the same survey, Mostofi et al. developed a structural equation model to explain how the attitude of ordinary citizen towards air taxis is formed. They find that the expected impact of pUAM on the overall quality of life in cities is a significant predictor for the attitude respondents have towards eVTOL operation in public spaces. Further, they observe aesthetic dimensions such as the blocked view to the urban sky, noise and induced stress due to traffic movements above one's head as negatively impacting respondents' attitude. Derived from these findings, the researchers advise pre-emptively minimising aesthetic risks in the choice and placement of vertiport infrastructure, in vehicle routing and in route frequentation [57].

To achieve this, however, urban planning practice must first embrace the lower urban airspace as a new subject for sustainable mobility planning. In this context, Kellerman et al. review aspects of urban planning and city development covered in the contemporary literature and conclude that local planning authorities are considered unprepared to integrate three-dimensional air traffic (infrastructure) into existing planning practice. More precisely, two lines of research have not yet been integrated into a comprehensive discourse. On one hand, requirements for an UTM/U-Space are supposed to allow for high traffic volumes and operational safety of drones. On the other hand, the researchers quote requirements for city planning authorities on the municipal or regional level to ensure a fair sharing of societal burden and individual benefits from drone related services. Cooperation will be required between different stakeholder groups such as commercial vertiport and air taxi operators, civil society, affected residents and customers. Proposed as a tool to facilitate this reconciliation are participatory planning practices [4]. However, it remains an open research question what issues participatory processes can mitigate effectively and how they can be implemented procedurally [58]. Relevant use cases are seen in the development of community guidelines for drones, to factor stakeholder interests in U-Space planning [43] or to mitigate drone related noise in a citizen science approach [59].

In the case of European regions and municipal authorities, the awareness for upcoming urban planning challenges and potential solutions is limited, as UAM developments in Europe have been focused strongly on model cities and regions. Those, however, have already advocated for a deciding role in the governance of local urban airspace, e.g., on the type of UAM services allowed as well as on the extent and territorial boundaries of services, including the decision on no-fly zones and the placement of take-off and landing sites [60]. While this legal authority on the regional or municipal level may facilitate greater adaption to local needs, other researchers suspect the economic feasibility of pUAM to decrease due to extensive operational restrictions within and between cities and regions [61].

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