sustainability

MDPI

Review

Social Sustainable Urban Air Mobility in Europe

Tobias Biehle

Department of Work, Technology and Participation, Technische Universität Berlin, Marchstraße. 23, MAR 1-1, 10587 Berlin, Germany; tobias.biehle@tu-berlin.de; Tel.: +49-(0)-30-31478844

Abstract: The first step to steer passenger Urban Air Mobility (pUAM) towards the necessity of sustainability is to understand its impact on our urban transportation systems. This research emphasises the social footprint of passenger drones in scheduled operation as an early business model in European Functional Urban Areas. The literature review is guided by the corresponding Sustainable Urban Mobility Indicators (SUMI). The prospective impact which the introduction of pUAM has on the evaluation of European transportation systems regarding their affordability for the public, their inclusivity for mobility-impaired groups, their accessibility to commuters and the level of customer satisfaction is analysed. Furthermore, the impact of pUAM on the perceived quality of public urban space is examined. Results indicate the overall social footprint of passenger drones in European transport systems to be negative. Early market pUAM may lead to an unbalanced distribution of potential benefits, with services tailored to address only a limited number of citizens. Highlighting pathways for a societal benefiting technology, recommendations are provided for urban planning and city development.

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

check for updates

Citation: Biehle, T. Social Sustainable Urban Air Mobility in Europe. *Sustainability* **2022**, *14*, 9312. https://doi.org/10.3390/su14159312

Academic Editors: Vittorio Di Vito, Gabriella Duca and Raffaella Russo

Received: 27 June 2022
Accepted: 26 July 2022
Published: 29 July 2022

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 our 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 our 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 review 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].

Business cases that are explicitly considered in the analysis are inner-city commutes and pUAM as linkage between city and periphery, e.g., satellite cities, suburban or rural areas [11]. Any service provision is thereby dependent on dedicated ground infrastructure for passenger access and egress, so called vertiports. The vehicles are considered piloted, battery-powered and able to vertically take-off and land (eVTOL) with two to five passengers on board. Booking will be conducted by digital means as part of the Mobility as a Service (MaaS) environment [12]. As it is expected for early market operation, pUAM services in this analysis are assumed to be scheduled operations between limited numbers of attractive, urbanised locations [13]. However, on-demand operation will be considered as part of the discussion and outlook. Within this analytical framework, substantiated prospects can help to assess the impact that an introduction of pUAM services will pose for the social sustainability assessment of European urban transportation systems. The findings may help authorities and planners to reflect a suitable role for pUAM in urban development and to steer a potential technology implementation towards the most vital target of sustainable mobility. What is more, the findings may contribute methodologically to a further adoption of SUMI towards new forms of aerial transportation.

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" [14]. 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 [15]. 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 authors refer to the triad of ecological, economic and social pillars of sustainable mobility (e.g., [16–18]). 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 our 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 [19]. 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 [20].

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 [19]. 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 [21].

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 [21,22].

3. Methodology

This study utilises these SUMI to assess pUAM on its prospective impact on transportation systems in European FUAs. The methodological approach is to review the current literature to understand the prospective positive and negative implications of a pUAM introduction on the relevant indicators and, with this, on the overall social sustainability rating of urban transportation systems. It is to note, however, that the applicability and integrity of the indicators of pUAM characteristics have not yet been tested. In addition, while conventional air and water transportation is excluded from an assessment of a city's transportation system via SUMI, authors do call for the indicators to be revised and adopted with regard to the impact assessment of emerging transport technologies that stem from the electrification, automatisation and digitalisation of urban mobility [23]. To this end, this article makes its contribution.

3.1. Adoption of SUMI on pUAM Characteristics

Preliminary work through a specific framework for the evaluation pUAM stems from al Haddad et al. [24]. The authors suggest a list of Key Performance Indicators (KPIs) to assess the environmental, socio-economic and transport potential of pUAM in the FUAs of Upper Bavaria, Germany. To do so, a multi-criteria decision analysis was preformed whereby experts weighted indicators in terms of relevance and measurability. A final selection was made using a threshold method. In order to assess the validity of the selected KPIs, they compared them with the SUMI. On the social dimensions of sustainable urban transportation, mutually supported are the affordability or equity indicators and inclusivity indicator. Exclusive to SUMI remain the access to the mobility services indicator, the satisfaction with the transport service indicator and the impact on the quality of public spaces indicator. On the other hand, the quality of life/welfare indicator and the privacy disturbance indicator are proposed from the authors [24]. As both dimensions address specific characteristics of pUAM, they are going to be reflected in the following adoption of the original SUMI framework as recognized by the Directorate-General for Mobility and Transport of the European Commission. For indicator definitions see [25].

Affordability of public transport for the poorest group indicator: The indicator recognizes that public transport should be affordable for all parts of society in order to make them equally available in social and economic life. It is originally measured by the share of the poorest quartile of the population's household budget required to use public transport. In the context of pUAM, the indicator is particularly relevant as concerns exists that future services will only address high-income households or business travellers [26]. Hence, the expected cost structure and future price development of pUAM is reviewed from the literature in relation to average household incomes.

Inclusivity for mobility-impaired groups: The standard of this indicator is to ensure that people with reduced mobility can actively and fully participate in society rather than experience discrimination and accessibility restrictions on public transport due to their condition. From the original indicator, persons with reduced mobility can be quoted as "those with visual and audial impairments and those with physical restrictions, such as pregnant women, users of wheelchairs and mobility devices, the elderly, parents and caregivers using buggies and people with temporary injuries". Including people with intellectual disability or impairment in this definition, the issue of reduced mobility is prevalent for around 87 million people in the European Union alone [27]. Passenger UAM-related services should therefore not create new barriers for people with disabilities but allow them to enjoy the benefits of this innovation on an equal basis to customers without impairments.

Access to mobility services indicator: All neighbourhoods in a FUA should be meaningfully connected to public transport in order for people to equally participate in social and economic life. The indicator synthesises both averages, of how much distance people have to bridge in order to reach public transport services and how often these services are provided for the respective locality. Threshold values were defined for this in SUMI, e.g., in a metropolitan area, poor accessibility would be accorded if people need less than 10 min to reach their local railway, but only if this station is served less than four times an hour. Thus, the assessment of whether pUAM services meaningfully increase the access to urban transportation systems will depends foremost on the spatial distribution of vertiports, their reachability for customers within the respective catchment areas and their operational performance.

Satisfaction with public transport indicator: The satisfaction with public transport or a particular mode of transportation affects the actual usage. That in turn affects the potential to stimulate economic growth, social and territorial cohesion as well as positive environmental effects emerging from the public transportation system. According to SUMI, satisfaction can be measured by evaluating citizens' perceptions towards the affordability, safety, reliability and easiness to obtain a particular mode of transport. Hence, the more pUAM meets the expectations of the general public in these dimensions, the higher the satisfaction. Since services are not yet in place to evaluate actual user experiences, mainly results of acceptance research will be reviewed, in particular on the willingness to use and pay for pUAM.

Quality of public spaces indicator: The quality of public spaces affects mobility behaviour and urban life quality. Designed to analyse results from the European Commission's Urban Audit, the indicator pools the satisfaction of local populations with public spaces such as pedestrian areas and green spaces such as parks. In a broader understanding, public spaces may be evaluated by their openness, by the physical and environmental relief and the welcoming sensory perceptions they provide, as well as by their vibrancy of safety and control that citizens feel when engaging in these places (cf. [28]). Regarding UAM, a changing perception of these qualities due to UAM vertiports as well as a novel degree of low-level air traffic will be considered in the analysis, including privacy and welfare implications as suggested by al Haddad et al. [24]. Results from acceptance research and the planning-related literature will be reviewed.

3.2. Literature Analysis

To derive prospects for the social sustainability of early pUAM services, a literature-based content analysis was conducted [29]. The relevant documents have been selected from two databases: Web of Science and Google Scholar. To structure the selection process, a list of English keywords was created [30]. Those were initially derived from the content dimensions covered by the SUMI and substantiated by pUAM-specific keywords provided from the KPI description by al Haddad et al. [24]. Boolean operators were used to refine the search. From the initial pool of articles found via the search engines, additional documents were identified via cross-reference searches [31,32]. Table 1 provides an overview on the adopted definitions of SUMI for pUAM and the deployed keywords to structure the document research.

Table 1. Summary on the adopted SUMI framework for pUAM and keyword search.

SUMI Adopted for pUAM:	Research Focus:	Keywords for Database Search:
Affordability of pUAM for the poorest	Budget required to use pUAM on a regular basis for commuting and inner-city travel	uam AND affordability OR equity OR operating costs OR pricing OR demand
Inclusivity of pUAM for mobility-impaired groups	Prospective accessibility of pUAM services and infrastructure to persons with reduced mobility	uam AND inclusivity OR accessibility OR equality
Accessibility of pUAM services	Spatial distribution of vertiports and their performance.	uam OR vertiports AND accessibility OR scalability OR modal share OR location OR distribution OR capacity OR performance OR passenger handling
Satisfaction with pUAM	Perceived satisfaction of using pUAM, especially regarding its safety, affordability, reliability and easiness to obtain/convenience	uam AND user adoption OR acceptance OR satisfaction OR reliability OR affordability OR safety OR convenience
Impact of UAM on the quality of public spaces	Impact of pUAM and related infrastructure on the perceived satisfaction with public spaces and on the quality of urban life/welfare.	uam OR vertiports AND visual pollution OR privacy OR public spaces OR urban quality OR acceptance

Forty publications have been selected. Besides technical papers from academic and public agencies such as the European Union Aviation Safety Agency (EASA) and National Aeronautics and Space Administration (NASA), only peer-reviewed articles and, where necessary, conference papers were considered. In regard to the constant gain of knowledge in the field and to extend the scope of former reviews [4,33], this analysis focused on publications from the year 2020 onwards. Excluded from this guideline are key sources, e.g., the literature in fields with low publication density. The analysis was performed using the qualitative content analysis software Atlas.ti (version 9), which allows the management of larger data sets [34]. Codes were created deductively from the five indicators. The collected codes in each analysis category were then summarized on content level [35].

4. Results

On the basis of the literature analysis, prospects for the implementation of pUAM and its expected impact on the relevant indicator for the social sustainability of urban transportation systems in Europe is presented.

4.1. 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 [36,37]. 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 [38], 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 [39]. 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.

4.2. 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 author 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 [40] (p. 6).

If and to what extent current private sector development is anticipating this appraisal cannot be assessed from the literature. However, authors 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 [41]. 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 [42]. 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 [43,44]. Finally, missing inclusivity standards might impact the overall customer satisfaction and public perception of pUAM negatively, hence pressuring manufactures and operations to adopt [13].

4.3. 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. [44]). Primarily, high demand stems from agglomerations of commuters traveling between transportation hubs, residential and business districts of a metropolitan area [11]. 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 [45].

4.3.2. 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 [37]) presents a relevant factor for pUAM services to realise overall travel time savings compared to competing means of ground transportation [46]. 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 [47–50].

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 m^2 in size [51]. 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 [52]) 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 [53]. 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 [33]. 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 [54]. 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 [55] p. 88. Factoring in these aspects, authors point out that operational requirements of vertiports in interchange to questions of residential acceptance could be lower on private industrial and commercially used spaces [42]. 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 [56].

4.3.3. 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 [57]. The authors 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 authors 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 [52].

4.4. 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 [58] 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 [59] 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 [60]. 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 [55] p. 62. Thus, the usefulness and advantageousness over its alternatives will be a decisive factor for customer satisfaction with pUAM.

4.4.1. 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 [55] 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 [58] 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) [61]. 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 [62]. Similar results can be found regarding the future potential for fully automated [60] or autonomous [59] eVTOL operation in passenger transportation respectively. Authors 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 [59,60]. Comparable results have been suggested in relation to automated long-haul aircrafts [63]. 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 [64] or at least some sort of security monitoring in the aircraft cabin, respectively [60].

4.4.2. 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. [65]). 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 [66]. 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 [67] (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 [38] (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. [38,39]). 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 [64], closely reaching the realistic cost estimation made by Goyal et al. [38].

4.4.3. Perceived Service Reliability

As research shows, the perceived service reliability, e.g., on-time performance [60] and low performance risks [68] 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 [68]. 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 [52].

4.4.4. 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 [11,60,61]. 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 in this research 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 [69]. 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 authors request further engagement in this field to ensure "that the passenger's first ride is not also their last" [13] p. 3.

4.5. 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 [55] 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 [58] 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 authors advise pre-emptively minimising aesthetic risks in the choice and placement of vertiport infrastructure, in vehicle routing and in route frequentation [70].

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 authors 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 [71]. Relevant use cases are seen in the development of community guidelines for drones, to factor stakeholder interests in U-Space planning [56] or to mitigate drone related noise in a citizen science approach [72].

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 [73]. While this legal authority on the regional or municipal level may facilitate greater adaption to local needs, other authors suspect the economic feasibility of pUAM to decrease due to extensive operational restrictions within and between cities and regions [74].

5. Discussion

Based on the results presented above, impacts of pUAM on the social sustainability rating of urban transportation systems in Europe can be discussed.

Findings on **affordability** provide a clear prospect. With about EUR 70 for a 10-km inner-city short trip (cf. [39]), most citizens will find pUAM too expensive for regular use. The introduction of pUAM would negatively affect the affordability rating of a European urban transport system. Nevertheless, authors argue positively for the development of a mass market and, along with it, decreasing consumer prices over the coming decades [54]. The current prime aspiration are public subsidies in the provision of local and regional UTM/U-Spaces as well as for urban take-off and landing sites for cargo and passenger drones. In analogy to conventional aviation air traffic management and road infrastructure, it is argued that such public engagement may foster a return on investments due to increased business activity [5]. In addition, greater engineering and operating efficiencies are forecasted over the next decades. This may include: lower costs for batteries and aircraft through mass production; extended aircraft operation through improved battery capacity and rapid charging; the substitution of on-board pilots through autonomous flight capability and a decreasing demand for staff on the ground through the automation of passenger handling processes [38]. In contrast to these long-term forecasts, the evolvement of a pUAM mass market may become hampered by improvements in alternative mobility services that occur parallel to the maturation of pUAM. Those might favour a shift to more efficient and sustainable transportation offers, e.g., ground vehicle automation in connection with relevant network expansion, efficiency improvements and price reductions in urban and regional ground transport. What is more, sustainable urban development must be quoted as countervailing trend, leading to increased functional diversity, shorter travel distances and less urban sprawl [7].

Drawing back on the literature regarding the **inclusivity of pUAM for mobility-impaired groups**, the likelihood and extent to which inclusivity requirements will become considered by eVTOL manufactures and vertiport architects cannot be assessed. Statements, for example on whether it will be possible to accommodate mobility aids such as prams or wheelchairs were not found. To avoid economic liabilities in early market entrance for the special designs and operational adjustments, the possibility is given, however, that pUAM services will not adhere to accessibility standards as provided to mobility-impaired groups in public transport. The inclusivity rating of the respective transport system would thus decrease. Nevertheless, companies aiming to integrate pUAM in urban settings must perforce cooperate with local planning authorities. Presuming their obligation to ensure social equality in transportation, the compliance of pUAM providers with minimum inclusivity standards might be enforceable [33]. What is more, dual use synergies from eVTOLs for civil medical services and military emergency response might support inclusive design features of certain vehicles [75].

Concluding the sub-chapter on the prospective **access to pUAM services**, the construction of small vertiports for a pUAM touch-and-go configuration in inner-city districts receives favourable regulations. However, available space significantly limits vertiport capacities. In respect to the SUMI, this low capacity for inner-city pUAM would not meaningfully impact the accessibility rating of the respective area. While the possibility should not be excluded, the likelihood to which larger vertiports with more relevant throughput rate will be placed central into attractive catchment areas seems far lower. Potential financial, legal and acceptance restraints connected to the construction and operation of larger transport infrastructure in densely populated areas must be mitigated [76]. Adding the envisioned integration of pUAM into the MaaS environment, it appears more likely that feeder traffic such as taxi services must be used by customers to access and leave vertiports, placed in less populated neighbourhoods. For vertiports in suburbs, outskirts and rural areas the situation might prove different. Access to the transportation system may be limited, favourable space for new infrastructures might be available and fewer legal and social restrictions may apply, but so is customer demand for pUAM. A regular connection of these stations as a prerequisite for improving the accessibility of the overall transport system of a FUA would prove to be costly and unlikely be executed in demand-driven pUAM planning approaches. To mitigate this shortcoming on frequency, authors point out that vertiport operators may become open accessible transportation hubs, e.g., including drone delivery and ground mobility services [54]. Especially for vertiports that are facing less demand, such a model could lead to higher utilisation, more overall pUAM network connections and thus increased accessibility for citizen.

Concluding the review on the prospective **satisfaction** of citizen with pUAM, safety aspects must be considered especially significant for early market operation. Thereby, studies suggest that the safety perception is rather subjective, meaning that pUAM can be perceived as safe from one person who might have a higher trust in new technologies while another feels more insecure and less willing to use the service [60]. The same rationale is true for the perceived affordability of services, influenced by varying income levels [64]. Consequently, the satisfaction with future pUAM in these dimensions will differ amongst a population. Drawing on the literature, a broader satisfaction with pUAM in society could be achieved when aiming for a high safety perception, e.g., having a pilot on board (cf. [64]) and a pricing policy of around EUR 2 per kilometre and passenger (cf. [67]) while stable operation (cf. [68]) and travel time saving is ensured (cf. [55]). Nevertheless, early business models must be anticipated to follow demand-driven approaches. Based on the reviewed studies, the target group usually contains a high share of younger, technophile males with higher education and income, living and frequently commuting individually in FUAs [11,37,59,60,64]. Consequently, satisfaction with the urban transportation system would only improve for this subgroup, while the majority of citizen will not feel considered.

From the existing literature regarding the **impact of UAM on the quality of public spaces** it appears relevant to anticipate a negative impact of eVTOLs and infrastructure on citizens' perception towards the quality of urban public spaces. This impact might initially be smaller due to low traffic density. However, external traffic costs such as noise and stress for residents in the vicinity of vertiports and along corresponding flight corridors should be highlighted when operation increases. Aesthetic demands for a clear urban sky, e.g., in recreational areas are suggested to play a significant role in connection to a high sojourn quality. Privacy and safety concerns might additionally influence how citizens perceive public spaces in which numerus aircrafts are deployed [70]. If or to what extent the quality of public spaces deteriorates may depend on the balancing between economic interests for a permissive airspace usage on the one hand and citizen-focused governance on U-Space and vertiport planning on the other hand. From the point of analysis, it is seen as favourable if municipal and regional planning authorities become key decision makers regarding the configuration of their urban airspace to mitigate conflicting interests between different stakeholders on the local level. Besides a corresponding legal framework, however, urban planning competences would have to be strengthened and participatory procedures developed (cf. [4]). In support of this, urban planning, sociology and human geographic perspectives must be embraced in the sustainable development of urban airspace and its ground infrastructure components [77].

6. Conclusions

The first step to steer passenger Urban Air Mobility (pUAM) towards the goal of sustainable mobility is to better understand the impact of its introduction on our urban transportation systems. This analysis focused on the prospective impact of pUAM on the five dimensions of socially sustainable urban transportation as adopted from the Sustainable Urban Mobility Indicators (SUMI) framework. Overall, it is to conclude that 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.

Limitations: Due to the upsurge of literature on UAM and the selection of only two databases, it may not have been possible to include all contributions in the field of research. Nevertheless, a consistent picture of prospective planning requirements should have been drafted. Further, while a share of the cited literature in this analysis emphasises futuristic on-demand operation of autonomous air taxis, the frame of analysis in this research was on early market, scheduled operation in European functionally urban areas. Thus, the transferability of results may have been prone to errors. Finally, the results of this study remain on a conceptual level. A future technology assessment in the presented categories should be conducted as local case studies, factoring in the regional specifics, vehicle characteristics and operational model.

Relevance and outlook: The expansion of metropolitan transportation to low-level airspace seems pending. It is predictable that attractive European metropolitan areas will be confronted with business concepts as soon as the legal framework will allow. However, in analogy to the paradigm of sustainable urban development, the deployment of passenger Urban Air Mobility should follow a holistic approach from the start. For political stakeholders on the regional and local level, a forward-looking understanding on the opportunities and risks associated with the new mobility offer will be key in making confident decisions regarding an introduction. For planners, it becomes apparent that new competencies and creative solutions will be required to steer urban air mobility towards sustainable mobility for the common good. Chiefly, this challenge calls for the active engagement of civil society, as without stakeholder participation there is not only a risk of a societal rejection and division, but also of decisions being made that do not realise positive innovation potentials of this technology.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Acknowledgments: I acknowledge support by the German Research Foundation and the Open Access Publication Fund of TU Berlin.

Conflicts of Interest: The author declares no conflict of interest.

References

1. *SESAR JU European Drones Outlook Study Unlocking the Value for Europe*; Publications Office of the European Union: Brussels, Belgium, 2016; pp. 21–25.
2. Hader, M.; Baur, S.; Kopera, S.; Schönberg, T.; Hasenberg, J.-P. *The High-Flying Industry: Urban Air Mobility Takes Off. Urban Air Mobility—An Industry Takes Off. Investments Are over 20 Times Higher than Four Years Ago*; Roland Berger GmbH: Munich, Germany, 2020.
3. *SESAR JU European ATM Master Plan-Roadmap for the Safe Integration of Drones into All Classes of Airspace*; Publications Office of the European Union: Brussels, Belgium, 2018.
4. Kellermann, R.; Biehle, T.; Fischer, L. Drones for Parcel and Passenger Transportation: A Literature Review. *Transp. Res. Interdiscip. Perspect.* **2020**, *4*, 100088. [CrossRef]
5. International Transport Forum (ITF). *Ready for Take Off? Integrating Drones into the Transport System*; OECD Publishing: Paris, France, 2021.
6. Maheshwari, T.; Axhausen, K.W. How Will the Technological Shift in Transportation Impact Cities? A Review of Quantitative Studies on the Impacts of New Transportation Technologies. *Sustainability* **2021**, *13*, 3013. [CrossRef]
7. Mouratidis, K.; Peters, S.; van Wee, B. Transportation Technologies, Sharing Economy, and Teleactivities: Implications for Built Environment and Travel. *Transp. Res. Part D Transp. Environ.* **2021**, *92*, 102716. [CrossRef]
8. Straubinger, A.; Verhoef, E.T.; de Groot, H.L.F. Going Electric: Environmental and Welfare Impacts of Urban Ground and Air Transport. *Transp. Res. Part D Transp. Environ.* **2022**, *102*, 103146. [CrossRef]
9. *Redefining "Urban": A New Way to Measure Metropolitan Areas*; OECD: Paris, France, 2012; ISBN 978-92-64-17405-4.
10. Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR). *Neue Leipzig Charta-Die Transformative Kraft der Städte für das Gemeinwohl*; Bundesamt für Bauwesen und Raumordnung: Bonn, Germany, 2020; pp. 10–11.
11. Straubinger, A.; Kluge, U.; Fu, M.; Al Haddad, C.; Ploetner, K.O.; Antoniou, C. Identifying Demand and Acceptance Drivers for User Friendly Urban Air Mobility Introduction. In *Towards User-Centric Transport in Europe 2*; Müller, B., Meyer, G., Eds.; Lecture Notes in Mobility; Springer International Publishing: Cham, Switzerland, 2020; pp. 117–134. ISBN 978-3-030-38027-4.
12. Shaheen, S.; Cohen, A. Mobility on Demand (MOD) and Mobility as a Service (MaaS): Early Understanding of Shared Mobility Impacts and Public Transit Partnerships. In *Demand for Emerging Transportation Systems*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 37–59. ISBN 978-0-12-815018-4.
13. Edwards, T.; Price, G. *EVTOL Passenger Acceptance*; National Aeronautics and Space Administration, Ames Research Center: Mountain View, CA, USA, 2020.
14. *Commission of the European Communities a Community Strategy for "Sustainable Mobility": Green Paper on the Impact of Transport on the Environment*; European Commission: Brussels, Belgium, 1992.
15. Holden, E.; Gilpin, G.; Banister, D. Sustainable Mobility at Thirty. *Sustainability* **2019**, *11*, 1965. [CrossRef]
16. Litman, T. Developing Indicators for Comprehensive and Sustainable Transport Planning. *Transp. Res. Rec.* **2007**, *2017*, 10–15. [CrossRef]
17. Seabra, L.O.; Taco, P.W.G.; Dominguez, E.M. Sustentabilidade Em Transportes: Do Conceito Às Políticas Públicas de Mobilidade Urbana. *Rev. Dos Transp. Públicos-ANTP* **2013**, *35*, 103–124.
18. Indicators for Sustainability. In *Encyclopedia of Sustainability in Higher Education*; Filho, L.W. (Ed.) Springer International Publishing: Cham, Switzerland, 2019; p. 932. ISBN 978-3-030-11351-3.
19. Bebber, S.; Libardi, B.; De Atayde Moschen, S.; Correa da Silva, M.B.; Cristina Fachinelli, A.; Nogueira, M.L. Sustainable Mobility Scale: A Contribution for Sustainability Assessment Systems in Urban Mobility. *Clean. Eng. Technol.* **2021**, *5*, 100271. [CrossRef]
20. Jeekel, H. Social Sustainability and Smart Mobility: Exploring the Relationship. *Transp. Res. Procedia* **2017**, *25*, 4296–4310. [CrossRef]
21. Torrisi, V.; Garau, C.; Ignaccolo, M.; Inturri, G. "Sustainable Urban Mobility Plans": Key Concepts and a Critical Revision on SUMPs Guidelines. In *Computational Science and Its Applications–ICCSA 2020*; Gervasi, O., Murgante, B., Misra, S., Garau, C., Blečić, I., Taniar, D., Apduhan, B.O., Rocha, A.M.A.C., Tarantino, E., Torre, C.M., et al., Eds.; Lecture Notes in Computer Science; Springer International Publishing: Cham, Switzerland, 2020; Volume 12255, pp. 613–628. ISBN 978-3-030-58819-9.

22. Haghshenas, H.; Vaziri, M. Urban Sustainable Transportation Indicators for Global Comparison. *Ecol. Indic.* **2012**, *15*, 115–121. [CrossRef]
23. *European University Institute towards a Common European Framework for Sustainable Urban Mobility Indicators*; European University Institute: Fiesole, Italy, 2020.
24. Al Haddad, C.; Fu, M.; Straubinger, A.; Plötner, K.; Antoniou, C. Choosing Suitable Indicators for the Assessment of Urban Air Mobility: A Case Study of Upper Bavaria, Germany. *Eur. J. Transp. Infrastruct. Res.* **2020**, *20*, 214–232. [CrossRef]
25. Directorate-General for Mobility and Transport Sustainable Urban Mobility Indicators (SUMI). Indicators 1, 2, 6, 12, and 14. Available online: https://transport.ec.europa.eu/transport-themes/clean-transport-urban-transport/sumi_en (accessed on 24 July 2022).
26. Vascik, P.D. Systems Analysis of Urban Air Mobility Operational Scaling. Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2020.
27. European Commission; Directorate-General for Employment, Social Affairs and Inclusion; Grammeno, S. *European Comparative Data on Europe 2020 and Persons with Disabilities: Labour Market, Education, Poverty and Health Analysis and Trends*; Publications Office of the European Union: Brussels, Belgium, 2020.
28. Mehta, V. *The Street: A Quintessential Social Public Space*; Routledge: Oxfordshire, UK, 2013; p. 57. ISBN 978-0-203-06763-5.
29. Okoli, C.; Schabram, K. A Guide to Conducting a Systematic Literature Review of Information Systems Research. *Sprouts Work. Pap. Inf. Syst.* **2010**, *10*. [CrossRef]
30. Vom Brocke, J.; Simons, A.; Niehaves, B.; Riemer, K.; Plattfaut, R.; Cleven, A. Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. In Proceedings of the ECIS 2009, Verona, Italy, 7–10 June 2009; p. 161.
31. Hepplestone, S.; Holden, G.; Irwin, B.; Parkin, H.J.; Thorpe, L. Using Technology to Encourage Student Engagement with Feedback: A Literature Review. *Res. Learn. Technol.* **2011**, *19*, 117–127. [CrossRef]
32. Webster, J.; Watson, R.T. Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Q.* **2002**, *26*, 13–23.
33. Garrow, L.A.; German, B.J.; Leonard, C.E. Urban Air Mobility: A Comprehensive Review and Comparative Analysis with Autonomous and Electric Ground Transportation for Informing Future Research. *Transp. Res. Part C Emerg. Technol.* **2021**, *132*, 103377. [CrossRef]
34. Lu, C.-J.; Shulman, S.W. Rigor and Flexibility in Computer-Based Qualitative Research: Introducing the Coding Analysis Toolkit. *Int. J. Mult. Res. Approaches* **2008**, *2*, 105–117. [CrossRef]
35. Ando, H.; Cousins, R.; Young, C. Achieving Saturation in Thematic Analysis: Development and Refinement of a Codebook. *Compr. Psychol.* **2014**, *3*. [CrossRef]
36. Niklaß, M.; Dzikus, N.; Swaid, M.; Berling, J.; Lührs, B.; Lau, A.; Terekhov, I.; Gollnick, V. A Collaborative Approach for an Integrated Modeling of Urban Air Transportation Systems. *Aerospace* **2020**, *7*, 50. [CrossRef]
37. Rimjha, M.; Hotle, S.; Trani, A.; Hinze, N. Commuter Demand Estimation and Feasibility Assessment for Urban Air Mobility in Northern California. *Transp. Res. Part A Policy Pract.* **2021**, *148*, 506–524. [CrossRef]
38. Goyal, R.; Reiche, C.; Fernando, C.; Cohen, A. Advanced Air Mobility: Demand Analysis and Market Potential of the Airport Shuttle and Air Taxi Markets. *Sustainability* **2021**, *13*, 7421. [CrossRef]
39. Ploetner, K.O.; Al Haddad, C.; Antoniou, C.; Frank, F.; Fu, M.; Kabel, S.; Llorca, C.; Moeckel, R.; Moreno, A.T.; Pukhova, A.; et al. Long-Term Application Potential of Urban Air Mobility Complementing Public Transport: An Upper Bavaria Example. *CEAS Aeronaut. J.* **2020**, *11*, 991–1007. [CrossRef]
40. Young, L.A. *Accessibility Design and Operational Considerations in the Development of Urban Aerial Mobility Vehicles and Networks*; NASA Ames Research Center: San Jose, CA, USA, 2020.
41. Budd, L.; Ison, S. Supporting the Needs of Special Assistance (Including PRM) Passengers: An International Survey of Disabled Air Passenger Rights Legislation. *J. Air Transp. Manag.* **2020**, *87*, 101851. [CrossRef]
42. Straubinger, A.; Michelmann, J.; Biehle, T. Business Model Options for Passenger Urban Air Mobility. *CEAS Aeronaut. J.* **2021**, *12*, 361–380. [CrossRef]
43. Drabarz, A.K. Harmonising Accessibility in the EU Single Market: Challenges for Making the European Accessibility Act Work. *RECL* **2020**, *43*, 83–102. [CrossRef]
44. Rimjha, M.; Hotle, S.; Trani, A.; Hinze, N.; Smith, J.C. Urban Air Mobility Demand Estimation for Airport Access: A Los Angeles International Airport Case Study. In Proceedings of the 2021 Integrated Communications Navigation and Surveillance Conference (ICNS), IEEE, Dulles, VA, USA, 20 April 2021.
45. Rimjha, M.; Hotle, S.; Trani, A.; Hinze, N.; Smith, J.; Dollyhigh, S. Urban Air Mobility: Airport Ground Access Demand Estimation. In Proceedings of the AIAA AVIATION 2021 Forum, Virtual Event, 2 August 2021.
46. Pukhova, A.; Llorca, C.; Moreno, A.; Staves, C.; Zhang, Q.; Moeckel, R. Flying Taxis Revived: Can Urban Air Mobility Reduce Road Congestion? *J. Urban Mobil.* **2021**, *1*, 100002. [CrossRef]
47. Postorino, M.N.; Sarné, G.M.L. Reinventing Mobility Paradigms: Flying Car Scenarios and Challenges for Urban Mobility. *Sustainability* **2020**, *12*, 3581. [CrossRef]
48. Rath, S.; Chow, J.Y.J. *Air Taxi Skyport Location Problem for Airport Access*; Cornell University: Ithaca, NY, USA, 27 September 2021. [CrossRef]

49. Kleinbekman, I.C.; Mitici, M.; Wei, P. Rolling-Horizon Electric Vertical Takeoff and Landing Arrival Scheduling for On-Demand Urban Air Mobility. *J. Aerosp. Inf. Syst.* **2020**, *17*, 150–159. [CrossRef]
50. Jeong, J.; So, M.; Hwang, H.-Y. Selection of Vertiports Using K-Means Algorithm and Noise Analyses for Urban Air Mobility (UAM) in the Seoul Metropolitan Area. *Appl. Sci.* **2021**, *11*, 5729. [CrossRef]
51. European Aviation Safety Agency (EASA) Vertiports. *Prototype Technical Specifications for the Design of VFR Vertiports for Operation with Manned VTOL-Capable Aircraft Certified in the Enhanced Category (PTS-VPT-DSN)*; European Aviation Safety Agency: Cologne, Germany, 2022; p. 72.
52. Preis, L.; Hornung, M. Vertiport Operations Modeling, Agent-Based Simulation and Parameter Value Specification. *Electronics* **2022**, *11*, 1071. [CrossRef]
53. Rimjha, M.; Trani, A. Urban Air Mobility: Factors Affecting Vertiport Capacity. In Proceedings of the 2021 Integrated Communications Navigation and Surveillance Conference (ICNS), IEEE, Dulles, VA, USA, 20 April 2021; pp. 1–14.
54. Cohen, A.P.; Shaheen, S.A.; Farrar, E.M. Urban Air Mobility: History, Ecosystem, Market Potential, and Challenges. *IEEE Trans. Intell. Transp. Syst.* **2021**, *22*, 6074–6087. [CrossRef]
55. European Aviation Safety Agency (EASA) Full Report. *Study on the Societal Acceptance of Urban Air Mobility in Europe*; EASA: Cologne, Germany, 2021.
56. Biehle, T.; Kellermann, R. *Mind the Gap: Concepts and Pathways for a Societally Acceptable Future of UAS in Europe*; Sky Limits: Berlin, Germany, 2019.
57. *Northeast UAS Airspace Integration Research Alliance (NUAIR) High-Density Automated Vertiport Concept of Operations*; NASA: Washington, DC, USA, 2021; p. 116.
58. *Sky Limits Traffic Solution or Technical Hype? Representative Population Survey on Delivery Drones and Air Taxis in Germany*; Sky Limits: Berlin, Germany, 2020.
59. Winter, S.R.; Rice, S.; Lamb, T.L. A Prediction Model of Consumer's Willingness to Fly in Autonomous Air Taxis. *J. Air Transp. Manag.* **2020**, *89*, 101926. [CrossRef]
60. Al Haddad, C.; Chaniotakis, E.; Straubinger, A.; Plötner, K.; Antoniou, C. Factors Affecting the Adoption and Use of Urban Air Mobility. *Transp. Res. Part A Policy Pract.* **2020**, *132*, 696–712. [CrossRef]
61. Lim, C.; Kim, Y.W.; Ji, Y.G.; Yoon, S.; Lee, S.C. Is This Flight Headed Downtown?: User Experience Considerations for Urban Air Mobility. In Proceedings of the CHI Conference on Human Factors in Computing Systems Extended Abstracts, New Orleans, LA, USA, 29 April–5 May 2022; ACM: New Orleans, LA, USA, 2022; pp. 1–7.
62. Chancey, E.T.; Politowicz, M.S. Public Trust and Acceptance for Concepts of Remotely Operated Urban Air Mobility Transportation. *Proc. Hum. Factors Ergon. Soc. Annu. Meet.* **2020**, *64*, 1044–1048. [CrossRef]
63. Winter, S.R.; Rice, S.; Mehta, R.; Cremer, I.; Reid, K.M.; Rosser, T.G.; Moore, J.C. Indian and American Consumer Perceptions of Cockpit Configuration Policy. *J. Air Transp. Manag.* **2015**, *42*, 226–231. [CrossRef]
64. Ahmed, S.S.; Fountas, G.; Eker, U.; Still, S.E.; Anastasopoulos, P.C. An Exploratory Empirical Analysis of Willingness to Hire and Pay for Flying Taxis and Shared Flying Car Services. *J. Air Transp. Manag.* **2021**, *90*, 101963. [CrossRef]
65. Breidert, C.; Hahsler, M.; Reutterer, T. A Review of Methods for Measuring Willingness-to-Pay. *Innov. Mark.* **2006**, *2*, 8–32.
66. Merkert, R.; Beck, M. Value of Travel Time Savings and Willingness to Pay for Regional Aviation. *Transp. Res. Part A Policy Pract.* **2017**, *96*, 29–42. [CrossRef]
67. Balac, M.; Rothfeld, R.L.; Horl, S. The Prospects of On-Demand Urban Air Mobility in Zurich, Switzerland. In Proceedings of the 2019 IEEE Intelligent Transportation Systems Conference (ITSC), IEEE, Auckland, New Zealand, 27–39 October 2019; pp. 906–913.
68. Han, H.; Yu, J.; Kim, W. An Electric Airplane: Assessing the Effect of Travelers' Perceived Risk, Attitude, and New Product Knowledge. *J. Air Transp. Manag.* **2019**, *78*, 33–42. [CrossRef]
69. Rajendran, S. Real-Time Dispatching of Air Taxis in Metropolitan Cities Using a Hybrid Simulation Goal Programming Algorithm. *Expert Syst. Appl.* **2021**, *178*, 115056. [CrossRef]
70. Mostofi, H.; Biehle, T.; Kellermann, R.; Dienel, H.L. *Public Attitude towards of Air Taxis: SEM Model*; Technische Universität Berlin: Berlin, Germany, 2022.
71. Nentwich, M.; Horváth, D.M. *Delivery Drones from a Technology Assessment Perspective*; Institute for Technology Assessment Vienna (ITA): Vienna, Austria, 2018.
72. Eißfeldt, H. Supporting Urban Air Mobility with Citizen Participatory Noise Sensing: A Concept. In Proceedings of the Companion 2019 World Wide Web Conference, San Francisco, CA, USA, 13 May 2019; ACM: New York, NY, USA; pp. 93–95.
73. UAM Initiative Cities Community–UIC2. Manifesto on the Multilevel Governance of the Urban Sky. 2020. Available online: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi4tpzImJ35AhWny4sBHYHXCzEQFnoECAcQAQ&url=https%3A%2F%2Fwww.amsterdamdroneweek.com%2F-%2Fmedia%2Fproject%2Fevent-sites%2Famsterdam-drone-week%2Fadw%2Fdocuments%2F2021%2Fuic2-manifesto---multilevel-governance-of-the-urban-sky_wtih-supporting-cities_14dec2021.pdf&usg=AOvVaw1BaS3405ovyiW1VN54avg5 (accessed on 25 July 2022).
74. Decker, C.; Chiambaretto, P. Economic Policy Choices and Trade-Offs for Unmanned Aircraft Systems Traffic Management (UTM): Insights from Europe and the United States. *Transp. Res. Part A Policy Pract.* **2022**, *157*, 40–58. [CrossRef]

75. Biehle, T. Ständige Überwachung–Militärische Interessen im zivilen Drohnenmarkt Europas. *PROKLA. Z. Für Krit. Soz.* **2020**, *50*, 665–680. [CrossRef]
76. Liebe, U.; Preisendörfer, P.; Bruderer Enzler, H. The Social Acceptance of Airport Expansion Scenarios: A Factorial Survey Experiment. *Transp. Res. Part D Transp. Environ.* **2020**, *84*, 102363. [CrossRef]
77. Bauranov, A.; Rakas, J. Designing Airspace for Urban Air Mobility: A Review of Concepts and Approaches. *Prog. Aerosp. Sci.* **2021**, *125*, 100726. [CrossRef]