Advanced Air Mobility and the Noise Problem

Friedrich Thießen

Contact

Prof. Dr. Friedrich Thießen
Technical University of Chemnitz
friedrich.thiessen@wiwi.tu-chemnitz.de
Office: 0371-531-34174
Mobil: 0178-5720129

Bundesvereinigung gegen Fluglärm
Geschäftsstelle
geschaeftsstelle@fluglaerm.de
Agnes-Miegel-Str. 60
28279 Bremen

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Abstract

The article highlights the noise problems caused by AAM. Studies by aircraft manufacturers and research institutes are available. There are also analyses by the US Federal Aviation Administration (FAA) and European environmental authorities. The aim of this article is to review and evaluate their findings and to identify consequences for the further development of AAM in connection with the noise problem.

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How to get the noise of AAM under control

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The Concept of AAM

What is Advanced Air Mobility? AAM is a new concept of operating air transportation in cities, between cities and between cities and regions. According to the US Federal Aviation Administration (FAA), AAM air transportation is typically highly automated, electrically powered and has vertical take-off and landing capabilities. Such features can solve problems that have previously prevented flying in densely populated agglomerations, opening up entirely new perspectives for the aviation industry. According to the FAA, AAM promises a great future: "*more efficient, more sustainable, more equitable while creating thousands of great jobs*" [13]. The European Environmental Protection Agency Network (EPA-Network) also sees a bright future: "*It may be expected that all Europeans will start seeing and hearing drones regularly in their living area before 2030*" [5].

Business models

Roland Berger investigated which business models - known as "use cases" - could develop around the new types of aircraft [10]. Three promising models were distilled:

1. City cab / city taxi: On demand. Multicopter eVTOL. Passenger and pilot. For "autonomous flights" two passengers without pilot. Hand luggage. 10 to 50 km. Metropolitan areas.

2. Airport shuttle: From city ports to the airport. 15 to 50 km. Tilt-rotor eVTOL aircraft. 4 PAX plus pilot and luggage. Defined routes according to timetables.

3. Inter-city: Medium to long-range air taxi service (50-250 km) between cities too close to allow traditional air transportation or where land-based transportation infrastructure is poor. Vectored thrust eVTOL aircraft. Pilot plus 6 PAX plus baggage.

Other experts see further use cases in the commercial, military and private sectors. These include use in agriculture, construction, inspections with mapping and surveying, photography and videography, urgent medical deliveries and emergencies. In the private sector, the term "drones-for-fun" is being used.

The Noise problem

The aim of this article is to shed light on noise problems. The aircraft used either have more characteristics of helicopters or of traditional planes. They are mostly compromises of both types. Some call them hybrid machines.

The noise problem has two facets:

- One problem with inner-city flying is the small distance between the noise sources and people. The FAA speaks of "*concentrated urban environments*" in which AAM takes place, which causes particular noise problems.

- On the other hand, typical AAM aircraft produce novel noise structures with high sound pressures in unpleasant frequency ranges. Special psychoacoustic problems occur.

What does the US-Authority FAA say?

In fall 2024, the FAA presented a general regulatory proposal for AAM, which included noise aspects [6]. The FAA's primary goal was to create "*public safety regarding aircraft noise*". The problem was that the aircraft under development had very diverse designs with "*complex noise sources*". However, only limited data was available on the noise structures ("noise signatures") of the developing aircraft. For this reason, it was impossible to announce generalized rules ("standards of general applicability") at that stage. The FAA reassured that every aircraft is checked for compliance with the applicable standards anyway.

What is the European Approach?

Also in autumn 2024, the European Environmental Protection Agency Network (EPA Network) issued a statement on AAM [5]. AAM is predicted to have a bright future: "*Urban air mobility is expected to increase rapidly in the next few years*" [5]. The network found a generally positive attitude towards urban air mobility among the European population. At the same time, however, noise and environmental problems are the main concerns of the population. AAM aircraft are not quiet and have tonal fluctuations, whining or humming noise components that are perceived as particularly disturbing. In the eyes of the EPA network, this means that the noise problems pose a serious threat to the further development of the AAM and that an honest discussion must be initiated.

The noise characteristics of AAM aircraft

So what are the noise characteristics of AAM aircraft?

Usually, in air traffic, the "noise itself", i.e. the sound pressure or noise level, is considered first. Values of over 60 up to 80 or 90 decibels are quoted for AAM aircraft. To better classify or interpret such values, the noise is often compared with other means of transportation (aircraft, motorcycles, helicopters, cars, trucks, rail traffic) [5]. The result for AAM is: "*not very loud compared to other vehicles*". However, the question arises as to whether such comparisons are meaningful at all. This is discussed further below.

Next, the other "acoustic features" are considered. They show that noise from AAM aircraft is hardly comparable with noise from conventional means of transportation. The working group of European environmental authorities recognizes characteristics that are perceived as highly annoying and represent completely new "*dose-response-functions*". This is explained in the next section.

Methods of noise measurement

How do you measure the noise of AAM aircraft?

The measurement method poses a first problem. Conventional measurement techniques have adapted to classic air traffic with airport-based transport along defined flight routes. But such flying is not typical for AAM. Advanced Air Mobility in cities takes place right next to, above or even below the people affected. Sitting on the balcony, a drone diagonally below you starts its engine to take off. Then it suddenly hovers next to you, only to pull further upwards before switching to cross-country flight with a loud transitional noise.

How do you measure such noise using a standardized method in order to be able to assess it? AAM aircraft would have to be measured from all sides and from close and greater distances. Schäffer et al [11] measure the A-weighted sound pressure level at a distance of 1 m under free-field conditions and at a radiation angle of -30° to the rotor plane, i.e. below and to the side of the aircraft. It remains to be seen whether this is already the optimum method. It will probably be necessary to test many variants in order to find the one that correlates best with annoyance perceptions in all relevant situations.

The second problem is the special noise characteristics of AAM aircraft. This is the field of psychoacoustics, which breaks down noise into its components. The aim is to associate the different characteristics with negative (or positive) auditory sensations and health hazards. In the context of AAM aircraft, the characteristics of sharpness, roughness, tonality and impulsiveness become relevant [9] [12].

Sharpness is a sensation that is triggered by high-frequency components of a sound. Sharpness is level-independent. This means that at the same sound pressure level, a sound is perceived as more unpleasant if it contains more high-frequency components. This is the case with typical drones (see Fig. 1).

Roughness refers to overlapping frequencies in sounds that can be perceived as a changing impression of loudness. Typical AAM aircraft with many motors and rotors can contribute to multiple overlapping frequencies.

Tonality or sonority is about whether individual tones can be heard in a sound or whether there is only a toneless noise. Sounds with individual tones are usually perceived more negatively at the same sound pressure than if a diffuse soundscape prevails (Fig. 1).

If the volume fluctuates, this is recorded in the so-called *fluctuation strength* or *impulsiveness*. In case of very strong fluctuations (banging, ramming), people react with increased annoyance and even harmful frightening effects. The *impulsiveness* of a noise is used as a measure. In classic air traffic, it is rather low. The aircraft take off from a distant airport and then approach the noise receivers, i.e. the people affected, over a certain period of time, with the noise slowly increasing and then slowly decreasing again. The impulse content is low. In inner-city drone traffic, on the other hand, people are right next to the aircraft taking off and landing, and the volume can change much more quickly. The impulse content can be high.

What results do scientific studies show?

In its analysis from fall 2024 [5], the Working Group of European Environmental Authorities cites scientific studies that show the following: Quadrocopters and octocopters, most of which have been tested to date, have clear tonal components in the noise spectrum. There is also a high proportion of high frequencies (sharpness). Further investigations show how the loudness and sharpness of a drone noise depends on the operating mode (hovering, climbing, descending, cross-country flight), which indicates that optimizing the flight manoeuvres could lead to less interference. Fast overflights at high altitude are associated with the fewest complaints. Meanwhile, the take-off and landing phases prove to be stressful. During hovering flight, for example, air turbulence must be compensated for by the flight control system. This can result in unsteady, unpleasant acoustic signatures.

Overall, the available studies - so far mainly on drones - indicate that loudness (i), tonality (ii) and sharpness (iii), i.e. high-frequency noise components, as well as rapid volume fluctuations (iv impulsiveness) depending on the flight maneuver, are the most important negative elements of the noise spectrum.

To illustrate the problems, Fig. 1 shows a comparison of the noise spectrum of 4 different means of transportation. The high high-frequency content and the tonal components (visible as peaks in the spectrum) of the drones are clearly recognizable.

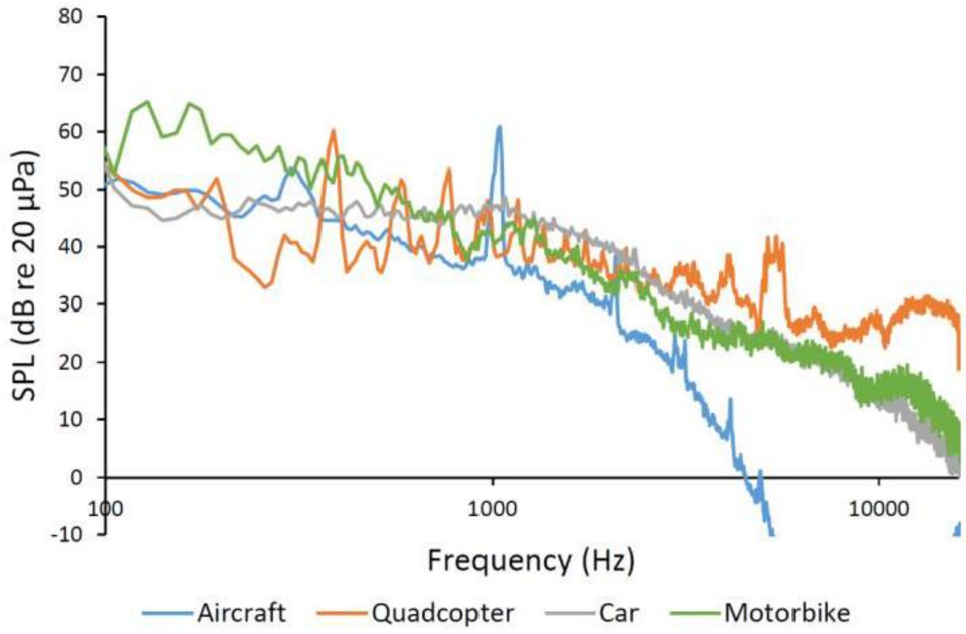

Fig. 1: Frequencies and volumes of different transport media
Source: EPA-Network [5], p.18.

The industry's response

How is the industry responding to the noise problem?

Manufacturers do not negate the noise problem. However, they use methods that trivialize it. They may be speculating that once the AAM business has taken off, the government will help to ensure that it does not have to be cut back again - e.g. because of the noise. One argument is that if noise reduction at the source led to an increase in the weight of AAM aircraft and at the same time, in order to protect people, noise abatement areas were built everywhere, the costs per flight kilometer could increase so much that AAM air traffic would become uneconomical from the outset.

A frequently used method by the industry to disguise the noise problem is to compare the AAM aircraft with other means of transport. Airbus, for example, approached the FAA with a comparison of unspecified AAM aircraft with the noise of large airplanes. The FAA rejected this comparison ([6] Sec91.129h).

Lilium from Germany compares the noise of their aircraft with various other means of transport and arrives at very favorable relative noise levels (see Fig. 2).

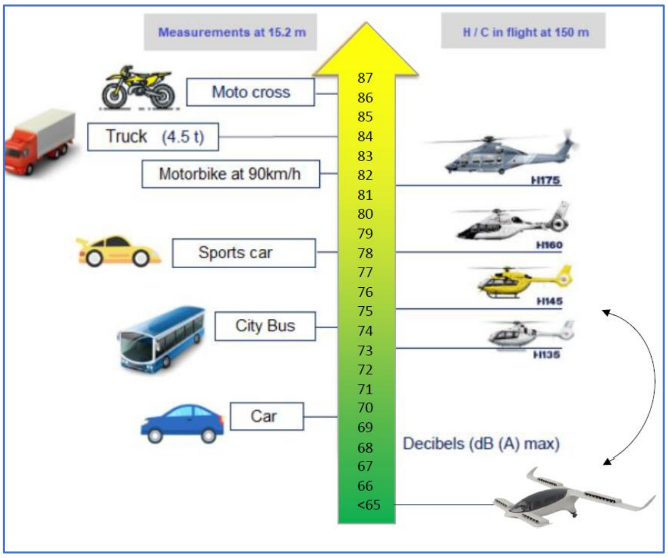

Fig. 2 “Noise comparison table” of a producer of AAM-aircraft
Source: Lilium (2023) [8]

Explanation: The figure shows how a manufacturer of AAM aircraft visualizes the noise problem. A comparison is made with alternative means of transportation. But it is not shown in which situations noise occurs and which comparisons are appropriate or not appropriate.

Joby Aviation (https://www.jobyaviation.com/) and Archer Aviation (https://archer.com/), both of which want to offer shuttle services between JFK Airport in New York and heliports downtown NYC, argue that their aircraft is virtually inaudible against the backdrop of typical noise levels in New York. Archer claimed that its Midnight eVTOL model is up to 100 times quieter than a helicopter at cruising altitude, making it virtually inaudible from street level.

How do the supervisory authorities react?

Regulatory authorities tend to reject simple comparisons at the level of noise sources. It is not the comparison of emissions at the source, but the exposure from the perspective of those affected, i.e. the immission at the noise receivers, that is decisive. To do this, the noise must be related to the specific flight situation. You cannot take a machine “per se”, such as a device operated in a laboratory, and compare its noise level with another machine “per se”. It depends on the specific “*flight situation*” in which the machine generates a certain noise and thus affects noise receivers. As AAM aircraft “*fly relatively close to people and houses, the noise immission can be significant at the level of those affected*” (quote from the Working Group of European Environmental Authorities [5]). A conventional aircraft is never that close to people.

In densely populated agglomerations, people cannot avoid new sources of noise. The majority of people's daily lives take place in these cities. European cities typically consist of a network of noisier main roads with quieter side streets. The typical appearance of European cities is the block structure of buildings. The blocks or carrés are exposed to the (traffic) noise of the city on the outside, while the inner courtyards of the blocks tend to be quiet, where you can escape the stress of the city. With AAM, the noise comes directly from above into the formerly quieter carrés.

Noise at the affected parties instead of noise at the source

In summary, this means: The decisive factor for the noise assessment of AAM is not the aircraft per se. To put it bluntly, they can be as loud as they like. The decisive factor is the noise from the *receiver position*, i.e. from the perspective of those affected by the noise. In densely populated agglomerations, there are new types of flight situations that occur as part of the various business models. The noise arriving at the receivers is the most relevant.

The fading out the specific flight situations

As a consequence, it is necessary to consider the *flight situations* that can occur with AAM and to identify the people affected in each case. In a second step it has then to be determined how much noise people should be expected to tolerate in that flight situations.

How are the specific flight situations currently handled? If you look at the industry's advertising material, you will see that it is precisely here, i.e. in the flight situations under consideration, that you will often find very embellished information and representations. However, this does not only apply to the industry. Associations, supervisory authorities and political brochures contain similar examples.

Fig. 3: Promotional film with transport drone dropping off goods
Source: Manna Drone Delivery; https://www.youtube.com/watch?v=oTJKo15rqtc

Fig. 3 on the right shows a transport drone from a promotional film by a delivery service delivering a parcel with ordered groceries - on the edge of a forest-like green zone. If the aim of the business model was to deliver things to forests, that would be ok. But it's about urban families living in an urban environment. In such a business model, how representative is the forest-like flight situation shown, where nobody is disturbed?

Fig. 4 shows a vertiport on a pontoon, with the surroundings faded out. The entire flight situation does not appear. You only see the water and the pontoon.

Fig. 4 Vertiport on a pontoon
Source: Lilium 2023 [8]

Explanation: The illustration visualizes a Vertiport on a pontoon on a river or lake. There are no residential buildings around it. The detail has been selected in such a way that any proximity to residential buildings and resulting conflicts are concealed.

Fig. 5 shows a transport drone in action from a German government brochure. Obviously, this operation takes place far away from the city and the homes of those affected. Where the drone could drop its load is vaguely indicated by the blurred background. However, the critical flight situations of the transport mission are hidden. Only an absolutely uncritical situation is shown, in which nobody would have anything against even the loudest drones.

Fig. 5 Drone delivery
Source: Government-Publication (2020) [2]
Explanation: Drone delivery from the perspective of the German Federal Government.

Fig. 6 shows the advertising brochure for an ICAO conference from 2024, in which AAM air traffic is depicted in a large city. Again, the flight situation is chosen so that those affected do not appear and seem far away. Even the distance to the high-rise office buildings is large. Residential buildings do not appear at all.

Fig. 6 AAM-aircraft in a big city
Source: ICAO [7]

Fig. 7 shows that the FAA also has such visualizations in its program. The flight situation depicted is chosen in such a way that a large distance is shown between the high-flying AAM aircraft and the much lower-lying human dwellings.

Fig. 7 Drone traffic high above a city
Source: FAA Internet (2025) [13]

Explanations: The scene shows a flight situation that takes place high above a city. There should hardly be any noise problems in such a flight situation.

In summary, it can be said: Almost unanimously, companies in the industry, associations, supervisory authorities and politicians visualize business models of AAM in such a way that no noisy flight situations are depicted. Buildings are far away. Residential buildings do not appear at all. Deliveries are made in green zones without disturbing people.

Actual flight situations

The examples shown make it clear that the more promotional media mainly show flight situations where the people affected by the noise are far away and where there are basically no noise problems at all. Suggesting this is probably also the aim of the images.

What does reality actually look like?

Basic situation

We choose a typical urban structure as the starting point. As Fig. 8a shows, this consists of main roads that carry the majority of traffic. There are also side streets, which are much quieter. The development (building structure) of a city is typically block development with inner courtyards, which can be built on or planted with greenery and are shielded from traffic noise. In addition, there are open spaces and open areas in the city, which can be parks or playgrounds.

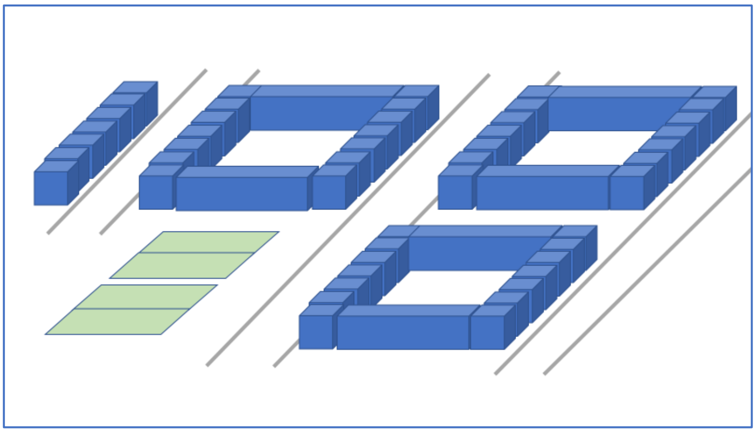

Fig. 8a Typical structure of European cities
Source: own

Explanation: The illustrations show a stylized urban structure. It consists of wider and noisier main roads (center) and quieter side streets (right and left). The buildings often have block structures. Occasionally there are undeveloped areas used as recreational zones.

AAM airplane on the ground

What is the situation when AAM aircraft are still at the ground, e.g. Vertiports? Vertiports are areas reserved for take-offs and landings in the urban environment (see above). Vertiports can be located on ground level or on the roofs of parking garages or similar, possibly also on pontoons on rivers and lakes.

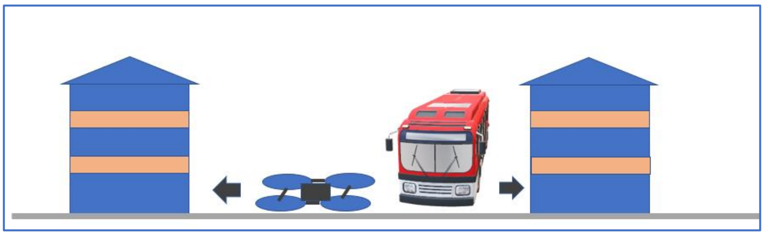

Fig. 8b AAM aircraft on the ground
Source: own

Explanation: The illustrations show the situation of a vertiport on the ground. The lower floors of buildings are affected by noise. A comparison of the noise with other means of transportation is permissible.

If AAM aircraft is on vertiports at road level, the noise of the AAM aircraft initially competes with that of other means of transport (see Fig. 8b). For this flight phase, i.e. the “preparations for take-off” and the “decay after landing”, comparisons with buses, cars or motorcycles are useful and permissible (see above). Many aircraft manufacturers make such comparisons and show that their devices are no louder than motorcycles, for example.

However, when making noise comparisons with other means of transportation, other aspects must also be taken into account, namely (i) the frequency of aircraft movements and (ii) the number of passengers transported: car traffic on roads is usually "frequent" and causes a permanent noise-background.

Buses and trains, on the other hand, travel in cycles, e.g. every 20 minutes, which generates noise that rises and falls. If AAM air traffic also took place every 20 minutes, but only carried a few passengers at a time, the benefit/noise ratio could be unfavorable. A comparison with the noise of buses and trains, which carry significantly more passengers per noise event, would not be valid. The correct comparison would rather be with means of transportation that also have a low transport capacity, such as terrestrial cabs. However, these have the advantage of causing practically no additional noise. This would then also be the requirement for AAM air traffic in this phase.

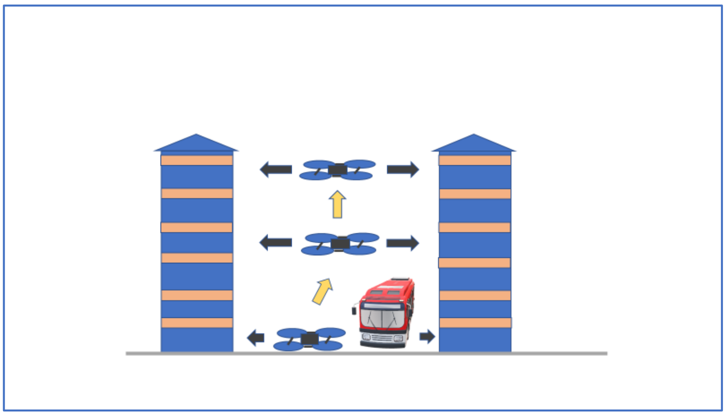

Fig. 8c: Situation during take-off and landing
Source: own

Explanation: The figure visualizes the first take-off phase. The AAM aircraft climbs up and makes noise on the higher floors of buildings. A comparison with other means of transportation on the ground is no longer permissible.

While Fig. 8b shows that an AAM aircraft using a vertiport in an urban area can be compared to other vehicles when and while it is on the ground, Fig. 8c shows that this is no longer the case after take-off. It approaches the quieter apartments on the higher floors and generates a new type of noise for the receivers that is not comparable to that of conventional means of transportation.

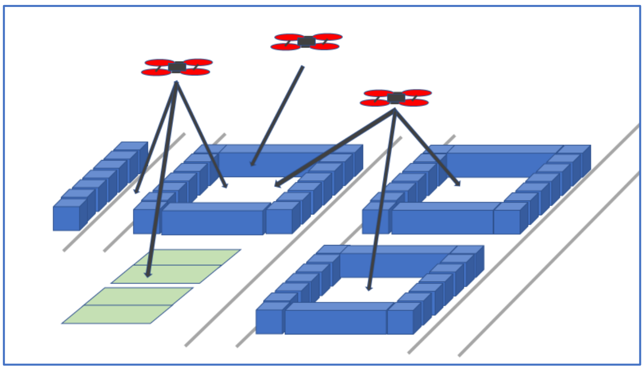

Fig. 8d Further ascent
Source: own

Explanation: The figure visualizes the noise propagation with a further increase in height. The noise penetrates from above into the quieter side streets and protected inner courtyards.

If the AAM aircraft then continues to ascend (Fig. 8d), the noise reaches the more protected areas of urban life: namely the previously quieter, traffic-calmed side streets, which are located away from the noisy main traffic axes, and also the quiet inner courtyards of the typical city block development.

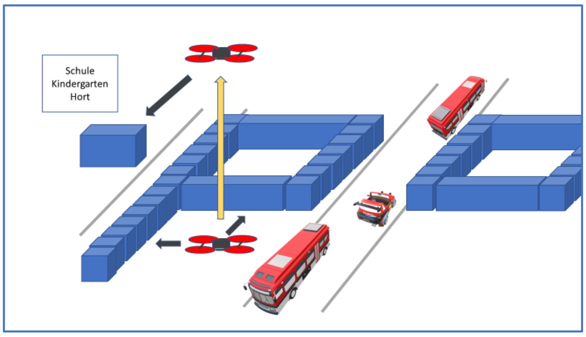

Fig. 8e Sensible city areas
Source: own

Explanation: Sensitive facilities such as schools or kindergartens are often located in noise-protected areas away from the main traffic areas. This protection is rendered obsolete by AAM because the noise reaches these locations the moment the AAM aircraft reaches enough altitude.

Fig. 8e illustrates that sensitive facilities such as schools or kindergartens, which are traditionally not built directly on noisy main traffic axes, can also be affected.

Transition movements

The transition movement is the change from take-off to cross-country flight or from cross-country flight to landing using VTOL or STOL technology. This transitional flight phase can be critical. In some cases, increased engine power is required during this phase. This can lead to increased noise emissions. Stressful frequencies have also been observed in some aircraft during this flight phase.

What are the consequences? Flight routes must be planned in such a way that the transmission phases are spatially located where sound pressure and frequencies are most compatible with the city. However, it is hard to imagine that it makes any sense at all to cover any part of a city - with the possible exception of commercial areas - every few minutes with the whine of an AAM aircraft in the transition phase. It is probably necessary to start at this point in the design of the AAM aircraft and prevent transition noise at this point.

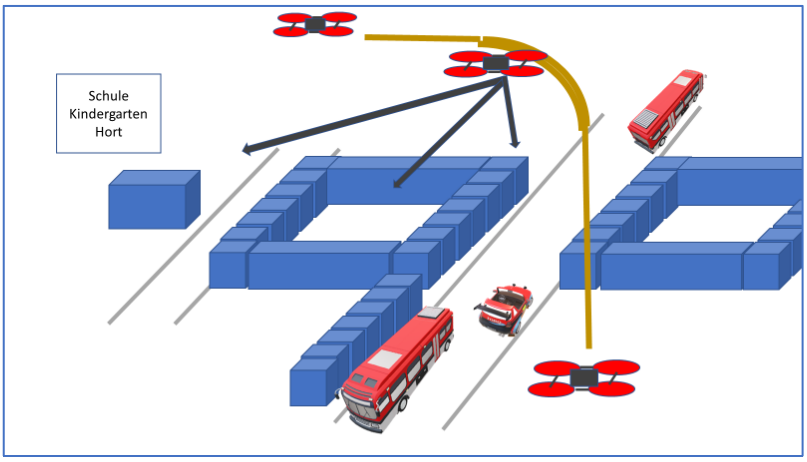

Fig. 8f Transition flight movement
Source: own

Explanation: The transition from vertical take-off and landing to horizontal cross-country flight can require special engine power and be correspondingly noisy. This can lead to unpleasant decaying and swelling noise.

Finally, Fig. 8g shows that flight paths can pass over side streets and inner courtyards, which were previously rather quiet, and cause noise in these areas.

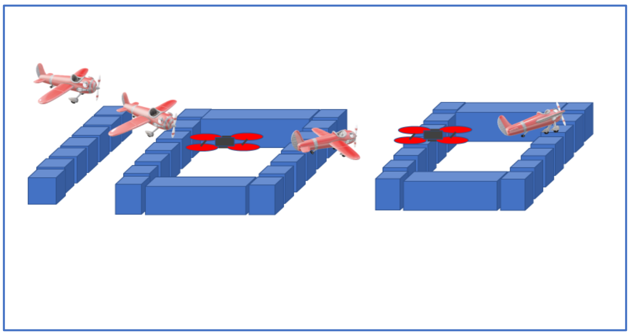

Fig. 8g Fly-over
Source: own

Explanation: The illustration points to the problem of flying over urban structures in order to reach vertiports. These can include areas that were previously spared from noise (courtyards in the picture or side streets).

Drone delivery

The delivery of smaller consignments of goods by drones has been discussed and tested for some time. The following situations arise:

- In isolated and remote areas, a cost-benefit-analysis could favor drone delivery even if there is considerable noise pollution, because the alternatives have particular disadvantages.

- In more densely populated areas, on the other hand, noise pollution can affect many people and lead to an unfavorable benefit/cost ratio. There are many alternative concepts for the delivery of goods in densely populated areas. There is no need to rely on drone delivery. Therefore, there is no reason to accept higher noise pollution.

Demand/suggestion: Permitted noise in densely populated areas should not exceed the level of an additional postal-delivery-van that drives down a street once a day to make deliveries.

Fig. 8h Drone delivery
Source: Government publication (2020) (left); own (right)

Explanation: How drone deliveries in rural areas are to be handled has not yet been worked out in concrete terms. The image on the right stylizes the activities of competing delivery services in one location. On the left is an effective advertising visualization of the federal government without reference to specific locations. The huge city in the background appears to be supplied by a single drone. Given the implied size of the city, there should actually be thousands, if not tens of thousands of drones buzzing around.

Conclusions and Consequences

What are the conclusions and consequences?

AAM aircraft are not as quiet as some had hoped. Electric flying is not comparable with electric car traffic. Sound pressure (volume) and specific acoustic phenomena (sharpness, roughness, tonality and impulsiveness) cause problems.

What is being done to solve them?

> - *Supervision.* In the opinion of US and European supervisory authorities, further research should be carried out into measures "*at the source*" that lead to lower sound pressures and a less disruptive noise quality of AAM aircraft. Work can also be done on optimizing flight manoeuvres to reduce their impact. Furthermore, no-fly zones and times are proposed and could be further investigated.
>
> - *Industry.* The industry warns against overly strict requirements for noise emissions from AAM aircraft, which could lead to the premature stalling of the new technology. A technology should not be regulated to death from the outset with unattainable requirements.
>
> - *Science.* According to the scientific literature, it is not important to minimize noise at the source. It is only important not to unduly burden the noise receivers where AAM air traffic takes place.

It is not the aircraft noise itself that is decisive, but the immissions that reach the noise receivers. You have to look at the flight situations and set specific noise limits there. The business models then adapt to these limits.

A vertiport in an industrial or commercial area or even in an office city cannot be confronted with the same noise regulations as a vertiport in a residential area. The noise limits still to be developed should therefore not focus on the aircraft itself, but on the respective flight situations and set limits there from the perspective of the affected noise receivers. Vertiports in residential areas, VTOL traffic along building facades, cross-country flights over previously quiet courtyards or side streets are critical flight situations that must be subject to strict conditions. In contrast, more freedom can be granted to flying in commercial and industrial areas.

This approach, i.e. the separate consideration of aircraft noise depending on the flight situation, does not restrict the development of AAM aircraft. Rather, it only makes it clear where stricter and where more lax rules are to be expected. This will steer the developing business models in the right direction from the outset. There will be aircraft that can only take off and land in industrial areas and on the outskirts of cities, and there will be aircraft that can be flown in the middle of agglomerations.

The limits do not even need to be set now: if developers and manufacturers know in which direction society is moving, they will easily recognize for themselves which business models will be feasible with their respective aircraft in which areas and which will not. Noise pollution of previously quiet urban areas such as inner courtyards or low-traffic side streets by AAM air traffic, which a few wealthy people use to have more fun or to get ahead faster than others, will not meet with social acceptance. For urban planning, this can mean thinking today about where vertiports and flight routes could be located in your city that can also be used by louder aircraft. Aircraft manufacturers can then adapt to this.

The regulators (FAA, Association of European Environmental Authorities) also suggest thinking about no-fly zones and no-fly times, but this was not examined further in this article.

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