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Noise simulation for UAM integration- Application to a health-care logistics system

Ulf Orrenius[1], Ulf Tengzelius[2], Pernilla Ulfvengren[3], Jan-Olof Ehk[4] and Mats Åbom[5]
[1] Akustikdoktorn Sweden AB
[2] Aurskall Akustik AB
[3]INDEK, KTH Royal Institute of technology
[4] Independent Business Group AB
[5] MWL, KTH Royal Institute of technology
ulf@akustikdoktorn.se

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Abstract

In the present work, the noise exposure from a logistics use-case of health-care logistics using UAVs is analysed. Based on ground transport logistics data between Stockholm's main acute hospitals, a scenario is developed for which three hospitals are connected by delivery drones, replacing three quarters of the transports of low weight priority parcels, which today are undertaken by ground vehicles.

Noise levels measured at hover and fly-over conditions from a state-of-the-art fixed-wing delivery UAV with 20 kg MTOL are used to define realistic source model representations. Based on realistic routes between the hospitals, accounting for ground risk and the restriction due to the 5 km risk zone encircling the Bromma airport, noise maps are calculated. For this purpose, SAFTu is used, a novel raytracing software dedicated to UAV and air taxi noise simulations. For the scenario analyzed, it is found that the sound levels calculated will generally not significantly add to noise levels in the city. Fixed wing delivery UAVs can be reasonably silent in wing mode operation and based on flying at 50 m above ground with in-situ measured source data, they will hardly be noticeable in relation to other city noise sources. On the other hand, the corresponding multicopter mode of operation is about 15 dBA noisier because of the need for lifting the entire UAV mass during flight. This difference suggests that the noise from drone operations can be strongly dependent on choice of technical solution.

Based on the results from the case analyzed, it is concluded that $L_{A,MAX}$ measured at building façades close to a new droneport installation rather than L_{DEN} levels (energy summation based) will govern the compliance with the noise exposure regulation if the current Swedish air traffic target levels are applied. From simulations using measured data from a state-of-the-art delivery drone at landing or take-off, it is found that the present Swedish $L_{A,MAX}$ air-traffic reference levels at building façades, will not be exceeded if the droneport is located at least 30 m from adjacent buildings. However, in view of the highly tonal character of UAV noise, it is not unlikely that future reference values may be lowered in relation to those from regular aircraft, both to reflect the annoyance perceived by exposure to noise from drones and also because a new kind of air-borne noise source may be experienced as intrusive, especially in environments previously unaffected by aircraft noise.

1. Background

1.1. Health care logistics with UAM

Drones, or so-called Unmanned Aerial Vehicles (UAVs), have a potential to facilitate more effective transport systems and are argued to help reducing the carbon footprint from the transport economy. The application of drones and piloted air vehicles in urban settings is termed Urban Air Mobility (UAM), a concept which can enable faster and potentially more reliable transport than corresponding ground-based alternatives. For example, an air taxi in Paris could lead to time savings between 50-75% for a city-to-airport transfer, compared to a car journey during rush hour [1]. In the same manner, urgent medical deliveries may get stuck in traffic, increasing the medical risk for patients [2].

For health care deliveries the main drivers for replacing ground vehicles with drones includes increased reliability of time-critical deliveries and reduced delivery times since drones will avoid traffic that may delay ground transports. In the case of using fossil-fuel driven cars in the alternative scenario, there could also be a carbon emission reducing reduction.

1.2. Noise management of UAM

However, when assessing the attitude from the public regarding UAVs integration, noise emerges as the second most significant concern after safety [1]. An increased use of UAVs in densely populated areas will cause noise pollution and may, if not accounted for, lead to negative health related effects like sleeping disorders, annoyance, as well as reduced learning capacity for residents near landing sites and flight paths [3]. If not properly addressed, noise will likely be a critical limiting factor for drone application and development [5]. Controlling the noise exposure caused by drone operations is therefore an important issue for regulators and aviation authorities.

Effectively managing noise emitted by UAVs is therefore crucial not only for its impact on health [4] but also for the acceptance of UAVs in society. Management noise in this context can be interpreted as controlling noise emissions such that the negative effects of acoustic disturbances from UAM as a transport solution are balanced with the added value of using UAM in relation to alternative transport means.

The primary UAV noise sources are typically the rotors and propellers. Multicopters must generate lifting forces from their rotors, also during flight, causing significant noise. Considerable in-flight noise reduction can be obtained by adopting fixed-wing technologies, for which the noise generated during flight is significantly less compared to multicopter-type UAVs. Certain noise and annoyance reduction can also be achieved by mitigation actions on the vehicle itself, by e.g. increasing rotor diameters for reduced tip speed at given thrust [5] or by using rotor shrouds [6]. Furthermore, for a given UAV type and transport scenario, the ground noise exposure can be managed through a well-balanced choice of flight routes, including consideration of the flight trajectory's height above ground in relation to relevant regulations regarding flight altitudes, ground risk and noise.

Noise exposure from UAM has received increasing attention lately. In reference [7], an air taxi UAM scenario for a German community is defined, and the effect of different approach strategies is investigated with respect to the annoyance and the fraction of the population disturbed. Due to the relatively low number of events and the low noise emission levels in the scenario analyzed, it was concluded that mainly the region in the direct proximity to the vertiport is affected. In reference [8] Tan and others develop a more complete scheme for analyzing flight paths and present a use-case with logistics UAVs in an urban area. The calculation scheme applied accounts for screening effects of buildings and in the paper different routes are assessed to determine the best route with respect to noise disturbance.

2. Objectives and delimitations

We investigate the noise exposure associated with a health-care use-case in Stockholm for which we assume that most of the small package deliveries between Stockholm hospitals are replaced by UAV transport using a state-of-the-art fixed wing delivery drone. We aim at comparing scenarios with respect to flight paths and choice of drone configuration and benchmark calculated noise levels to Swedish reference values. We also intend to illustrate benefits of working with noise maps as a basis for decision making and as a communication tool. We do not quantify or rate UAM noise disturbances in relation to other noise sources but discuss methodology for assessment and mitigation of noise from drones.

3. Method

3.1. Noise maps as a decision tool

Noise maps are extensively used as a tool in city planning to rate the noise exposure from novel infrastructure installations and for the planning of new housing and other kinds of commercial and public buildings including hospitals and schools. In addition, noise maps can be used to optimize investments in noise abatement measures like barriers and diffractors and as a tool to communicate noise control strategies and measures taken to protect the people affected [9]. Noise maps for UAM operation have similar potential as a planning and communication tool.

Within the Cnossos project [11] a common methodological framework for strategic noise mapping under the Environmental Noise Directive has been developed. The objective has been to improve the assessment of community noise by improved source descriptors and from 2019, it is mandatory to use the CNOSSOS-EU assessment methods in connection with strategic noise mapping. Levels are displayed in the EU indicators L_{DEN} and L_{night}. In Sweden, in addition to the EU indicators, sound levels should ideally also be reported as equivalent levels L_{EQ} and maximum levels $L_{A,MAX}$ (Swedish indicators) enabling a comparison to the corresponding Swedish reference values [12].

3.2. SAFTu: Software for UAV noise analysis

The SAFTu software is based on its predecessor SAFT [13][14]. Both codes are based on so-called simulation methods which, in contrary to the older "integrated methods" like INM and ECAC Doc.29, allows for studying moving vehicles/sound sources with arbitrary characteristics regarding sound source strength, directivity and frequency characteristics. The methods differ also regarding noise propagation modelling, where in SAFTu ray-tracing methods, and different atmospheric models, and data may be applied. Moreover, noise-contours can be determined and displayed based on any metrics since a time-frequency history can be calculated in all ground grid points. The SAFT methods are primarily developed for parameter studies in the case of single flight events but may also be applied for UAM air-traffic scenarios [14].

SAFTu is designed with simplicity in mind regarding input and running and effectivity in terms of computational speed. Currently an interactive input in a serial manner is followed: vehicle/source, region (within Europe), ground track, profile (including flight mode, e.g. "copter", "fixed wing" or "transition/mixed", when necessary). Based on given input data and previously established data, such as ground topography, a ground grid is computed before the main computation starts. This involves a discretization of the position of the sound source along the trajectory where emission of sound rays to the ground grid points take place. Here, the number of sound-rays/receiving points are limited to those witch significantly contributes to the resulting sound level on ground. The method with a "moving small-sized sub-grid" underneath the source, is very effective, resulting in a typical computational time of less than a minute, once input data is given.

Acoustic sources are generally represented in terms of their sound power, if needed also in combination with a directivity index, e.g. as defined in EN ISO 3744 [15], although additional measurement points may be required for a proper representation of the directivity. In SAFTu, the source is either represented by a monopole with uniform sound radiation in all directions, or by the sound intensity it emits in different directions projected onto segments of a sphere with a specified radius. This approach is equivalent to that stipulated in the ISO standard.

3.2.1. UAV sound source generation

For drones with electric motors, the rotors and the propellers are dominating the sound generation. The main sources are generally due to the interaction between the flow generated from the rotors and the UAV air-frame as well as corresponding interaction of the rotor blades and turbulent vortexes in the surrounding air and can be categorized in Blade-Vortex Interaction, Blade-Airframe Interaction, Fuselage-Wake Interaction, and steady rotor loading [5]. In addition, rotor pairs in a coaxial configuration typically implies strong inter-rotor interference leading to increased sound generation, and flow form rotors imbedded in ducts will interfere with the support structures (stators, vanes, etc.). In terms of the spectral characteristics drone noise spectra typically consists, of prominent tonal components in the low-to-mid frequency region, broadband noise in the mid-to-high frequency region, and electric motor noise in the high-frequency region. The relative strength of each of these components varies depending on the UAV size [16].

3.2.2. Multicopter directivity

Multicopter UAVs are somewhat directive when it comes to noise radiation, in particular at higher frequencies. In Figure 1 curve fitted directivity data $\Delta L_p(\varphi, \theta)$ are shown over a sphere. The data displayed are from fitting experimental data sets measured for five small multicopter UAVs (4-6 rotor, 0.8 kg > *m*>3.5 kg) in an echo free chamber [18]. The raw data used is in one third octave bands with center frequencies from 125 Hz to 12.5 k Hz normalized such that $\Delta L_p = 0$ at $\varphi = -30°$. These data were fitted with the least absolute residual robust (LAR) method using Matlab® [17] to a surface spanned by a second order polynomial in the frequency domain and to a third order polynomial in the φ-domain. The fitting is made over the lower hemisphere for $0° > \varphi > -90°$ using microphone data at the discrete angles of $\varphi = [30°, -30°, -60°, -80°]$, with reference to the coordinate system displayed in Figure 1. In the plots the field is mirrored in the x-y plane such that $\Delta L_p(\varphi, \theta) = \Delta L_p(-\varphi, \theta)$, that is the source is assumed to be symmetric with respect to the x-y plane. Moreover, the radiated sound power is also assumed to be constant with respect to the azimuthal angle θ, meaning that the sound radiation is the same for all angles in the rotor plane. To comply with the standard definition of directivity index according to ISO 3744, ΔL_p has been normalized so that the spatially averaged directivity is zero for all frequencies.

From Figure 1 we find that the direction perpendicular to the rotor plane is associated with the highest radiation. This directivity is more pronounced at high frequencies.

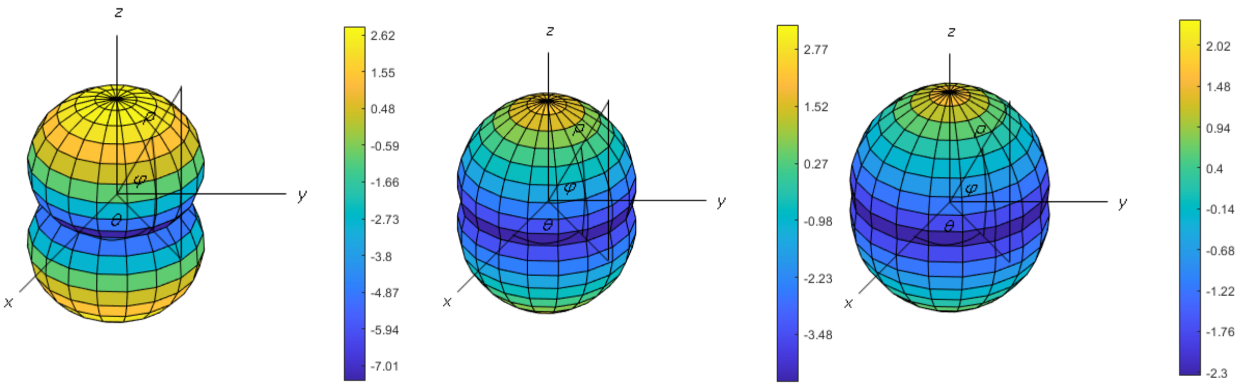

Figure 1. Multicopter directivity ΔL_p fitted to measured data: Left, 10 kHz; Center, 1 kHz; Right, 100 Hz.

3.2.3. Source representation in the case studied

In the present work, two different delivery UAV source representations are simulated. The first representation simulates a quadcopter mode of operation and the second a fixed wing mode of operation. The overall source strengths are obtained from data from in situ measurements on a delivery UAV with 20 kg maximum take-off mass as illustrated in Figure 2. The measurements were carried out as described in the EASA measurement guidelines [19] with A-weighted sound pressure levels recorded at fly-over and at hover configurations at 55 m and 25 m altitude respectively. No spectral data were available from the UAV analyzed. To complement with the spectral data needed for the SAFTu simulations, a simple and pragmatic algorithm was used based on the tonal components corresponding to the blade passing frequency of the UAV and its harmonics spectrum. The amplitudes of the Blade Passing Frequency (BPF) component and its harmonics were tuned to fit with a measured spectral shape on a similar UAV such that the harmonics decay by 2 dB per octave from the BPF till the fourth harmonic and by 10 dB per octave at higher frequencies. The amplitudes were then scaled to fit with the total A weighted sound pressure levels at 55 m and 25 m respectively as obtained from in-situ testing.

In Figure 2, sound pressure spectra 1 m from the source for the vertical and the horizontal propulsion units are plotted in 1/3-octave bands. It is clear that the push propeller propulsion in wing mode is much less noisy than the quadcopter mode rotors. Note that broadband noise from various aero-acoustic source mechanisms was not explicitly modelled here but the higher order harmonics are tuned such that they represent broad band noise as explained above. For the one-third octave band source representations applied in the simulations, the tonal components do not appear in the spectra above ca 0.5 kHz as displayed in Figure 2.

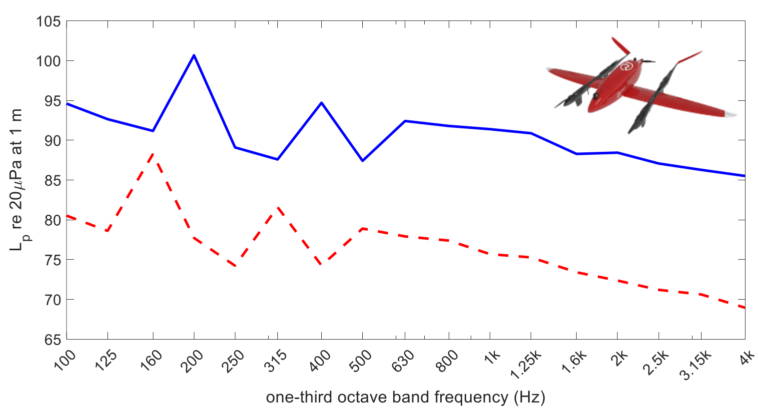

Figure 2. Sound pressure levels at 1 m from the vertical (———) and the horizontal (--------) propulsion units in 1/3-octave bands. Spectra tuned to field measured overall levels for the example UAV.

For the present source models, the sound radiation from the sources were taken to be the same for all angles (monopole sources). However, directivity was indirectly accounted for such that the source sound power was based on the in-situ sound pressure measurements directly below the UAV, meaning that for the quadcopter mode of operation the apparent sound power corresponds to the sound radiation in a direction perpendicular to the rotor plane whereas for the wing mode operation the apparent sound power is taken from measurements in the propeller plane. In this way the sound generation will represent the radiation directly below the UAV which in view of the data presented in Figure 1, and the diploe character of rotor sources, is a conservative estimate for the true radiation in other directions. Generic directivity data could potentially be accounted for to improve simulations, e.g., at a droneport at which landing drones radiate sound to surrounding buildings in their rotor plane direction.

4. Use case analysed

In the present work we focus on the increased noise exposure resulting from introducing UAM. Our use-case is a specific scenario, replacing a ground vehicle transport system with logistical UAVs for transport of packages between Stockholm's main hospitals as indicated in Figure 3 [5]. Between the five hospitals more than 5 000 packages are delivered yearly, of which 98% weighs less than 2 kg. Packages may contain crucial items, such as blood samples from hospitals to centralized laboratories or material and equipment from suppliers or other hospitals. A similar scenario interconnecting the tree largest Gothenborg hospitals by delivery drones is presented in [2].

Figure 3. Stockholm main acute hospital locations. From reference [19].

4.1. Stockholm air-space restrictions

Stockholm's airspace is heavily trafficked by manned aircraft and provides a challenging environment for drones. Bromma Airport is currently surrounded by a 5 km protection zone where drone flights are not allowed when the air traffic control tower is open at days and evenings, see reference [21]. In addition, a control zone extends over most of the central Stockholm area. The two different zones are depicted in Figure 4. Moreover, no-fly-zones surrounds helicopter landing sites at the hospitals etc.

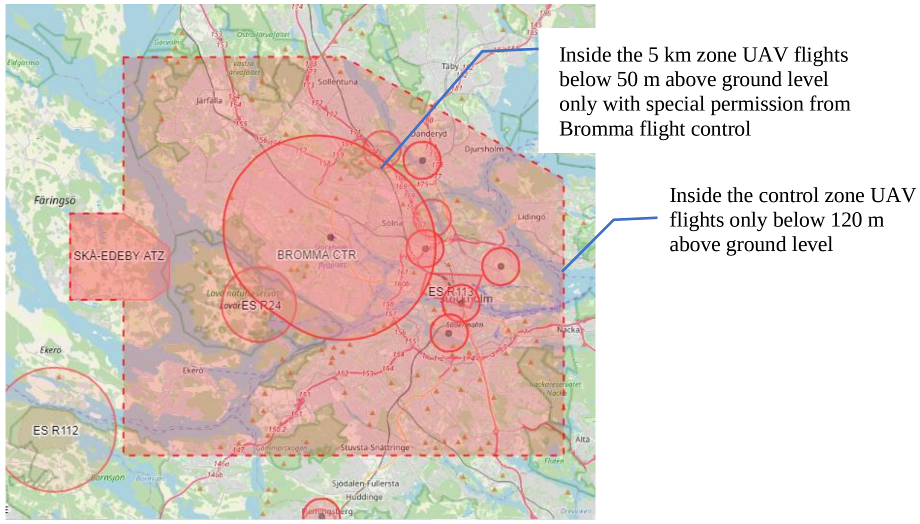

Figure 4. Bromma control zones. From reference [21].

4.2. Logistics scenario analysed

Regarding noise exposure, UAV routes between the three largest hospitals outside of the Bromma restriction area were analysed: South general, Danderyd and Huddinge hospitals. The potential number of UAV transports is determined from the present number of "priority" ground transports with a cargo mass less than two kg. Data for such ground transports were collected during a nine-month period 2022 as reported in [20]. In Table 1 the number of lightweight priority deliveries between the three hospitals are tabulated, recalculated to a 12-month period. Regarding a future transition to UAV delivery, it is assumed that 75% of the total number of deliveries can be managed by UAV whereas the rest must be transported by standard deliveries. The main reason for this reduction in UAV operation is the risk for icing with an anticipated operational limit based on: T > -10 ℃, precipitation < 3 mm/h, average wind < 10 m/s and visibility > 500 m. It is also assumed that 50 % of the deliveries result in an empty return flight in view of the urgency of this kind of deliveries.

Table 1. Number of annual priority deliveries between three Stockholm hospitals.

	Huddinge			South General			Danderyd			
	To	From	Total UAV	To	From	Total UAV	To	From	Total UAV	**Overall UAV**
Huddinge				401	715	1674	15	4	28	**1702**
South General	715	401	1674				271	625	1344	**3018**
Danderyd	4	15	28	625	271	1344				**1372**

From the traffic scenario analysed the daily exposure time to UAV noise in the vicinity of a hospital droneport is small. Based on the data in Table 1, the daily number of UAV take-offs and landings at the most frequently trafficked hospital (South General) would average at 8 per day resulting in a daily exposure time of about 1.5 minutes can be estimated, where it has been assumed a take-off/landing sequence of ca 12 seconds. If, in the future, also the other two hospitals as well as the MediCarrier central storage are included, the total number of UAV movements will be the highest at Karolinska Hospital with a total of ca 5000 movements per year, or 13 per day.

5. Results

5.1. Routing

From the frequency data of Table 1 and in view of the Bromma restrictions, a flight route between Huddinge Hospital and the South General Hospital was chosen to be analyzed regarding noise.

In Figure 5, three proposed flight routes with different ground risk are displayed.

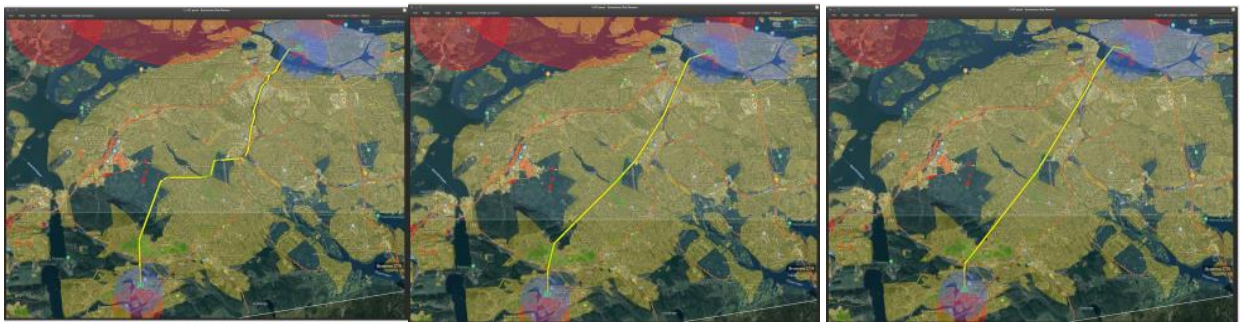

Figure 5. Huddinge - South General Route: Low ground risk route (left), medium ground risk route (center and right). Densely populated areas are marked with a blue colour. From reference [20].

For the definition of flight route, the no-fly zones surrounding hospital helipads have been respected, with exception for the hospitals included in the feasibility study for which coordination with the ambulance helicopters is required. Regarding ground risk assessments routes, were planned based on population density from GHSL[1]. For the low-risk flight route depicted to the left of Figure 5, an UAV system that meets the requirements of SAIL 2 has been assumed. Also, noise exposure was accounted for such that some routes were planned along railways and roads based on suggestions from representatives of the stakeholders.

In Figure 6 an illustration of the process to map the 13.9 km, low risk ground track in Google Earth using waypoints, is displayed along with altitude and speed over the resulting 10-minute flight sequence.

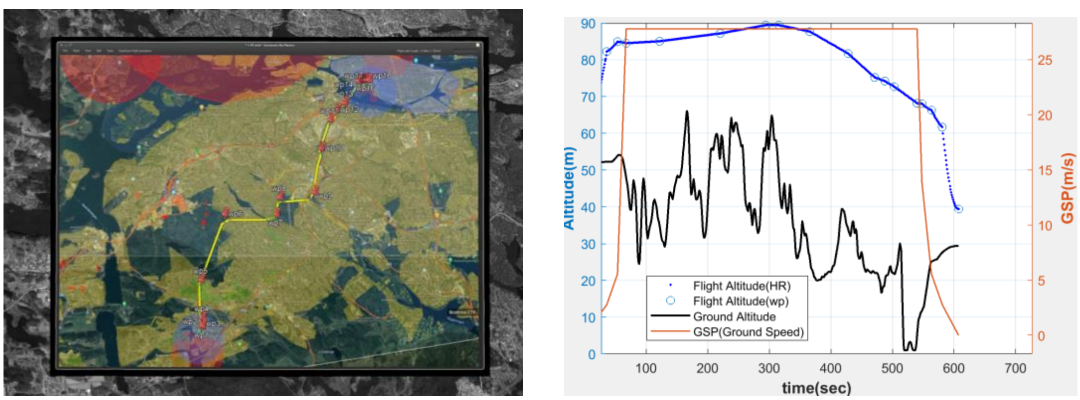

Figure 6. Huddinge - South General route: Ground track data on overlayed map transferred to flight routing in Google Earth via waypoints input(left). Altitude and speed over the flight time sequence (right).

[1] https://ghslsys.jrc.ec.europa.eu/ghs_pop2022.php

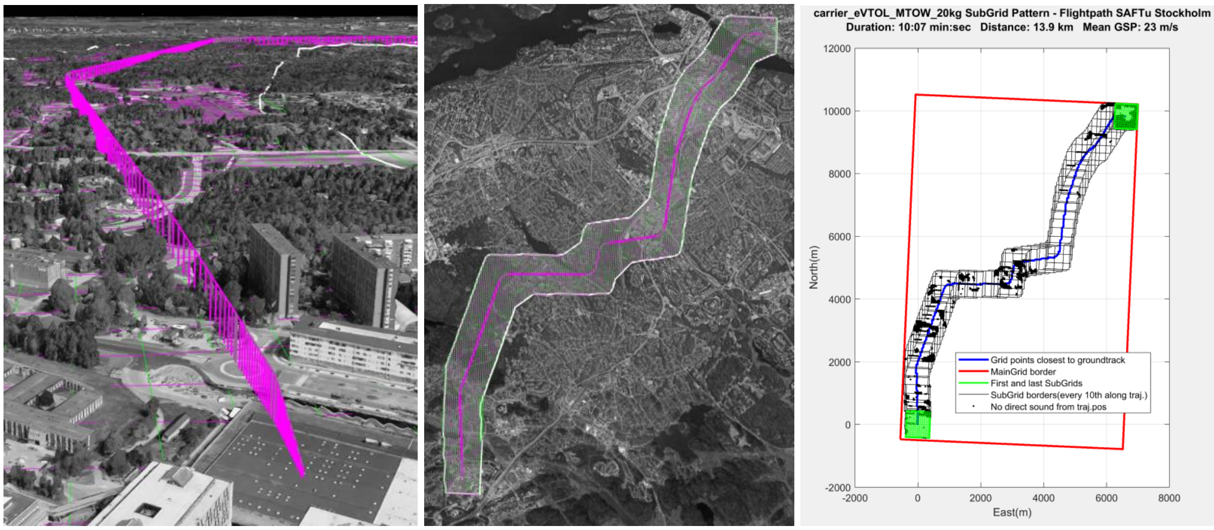

Figure 7. Discretized 3D trajectory displayed in Google Earth (left). Computational ground grid (center and right).

In Figure 7 representations of the ground grid are shown. To the left a discretized 3D trajectory is displayed in Google Earth together with the ground grid (mostly hidden due to buildings and vegetation) In the center, a computational ground grid is shown along the trajectory covering areas with significant noise levels. To the right the full ground grid is shown. The red rectangle defines the main grid area whereas the black and green rectangles along the ground track are "sub grid" borders of which every tenth is plotted. The black spots correspond to grid points not reached by direct sound rays due to screening from the topography.

5.2. Sound levels calculated.

In Figure 8 and Figure 9, calculated $L_{A,MAX}$ levels are displayed in noise maps for two different flight configurations. In the first the quadcopter mode is used for the entire flight whereas in the second the rotors are switched off right after takeoff. In a similar manner the rotors are turned on again before landing at South General Hospital. It is clear that the wing mode configuration results in a much quieter flight than the quadcopter mode.

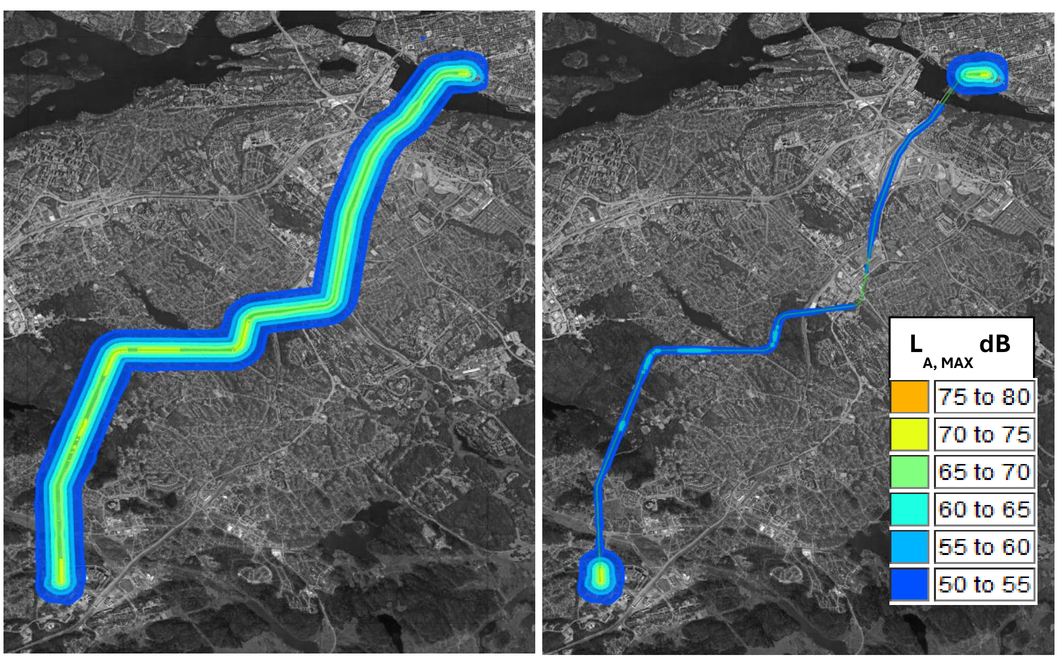

Figure 8. SAFTu noise maps for the quadcopter case (left) and the wing case (right).

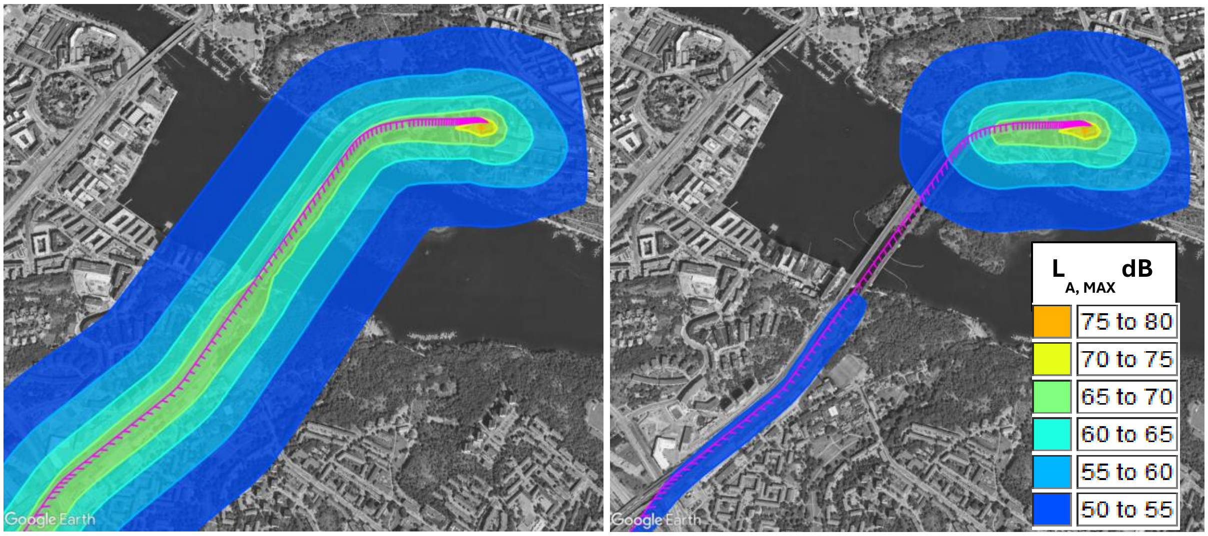

Figure 9. South General Hospital landing site noise maps for the quadcopter case (left) and the wing case (right).

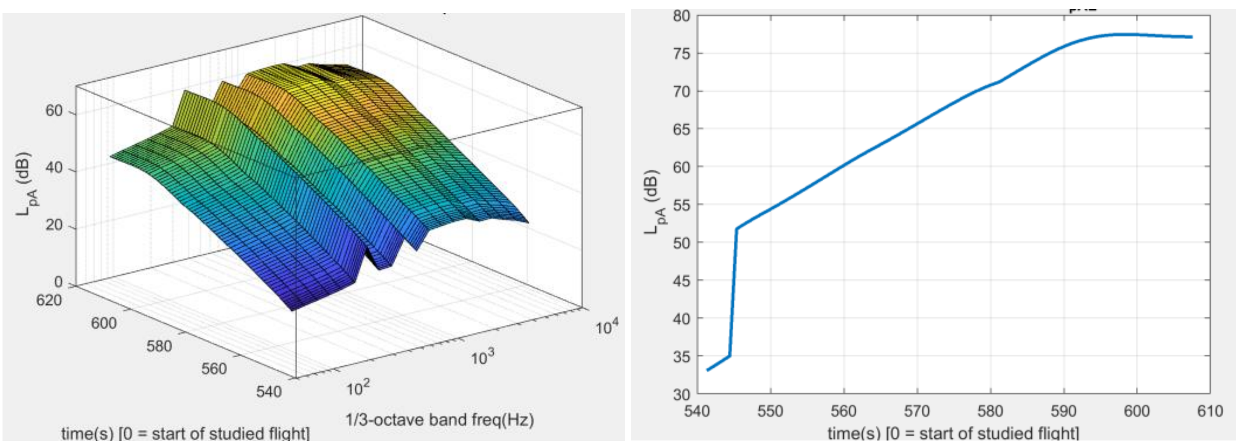

Figure 10. Time histories of sound pressure level in a grid point in the vicinity of the South General Hospital droneport.

5.3. Benchmark to current Swedish reference values.

The Swedish regulation on Traffic Noise at Residential Buildings (2015:216) contains guideline values for traffic noise. The statutes refer to outdoor values at homes and refer to road, rail and air traffic. The reference values are to be used as guidance in planning and in matters concerning building permits and advance notices, as well as in the examination of permits for airports under the Swedish Environmental Code and regulations issued referring to this code. According to Section 6, noise from airports may not exceed 55 dBA FBN[2] and 70 dBA maximum sound level at the façade of a residential building. Section 7 states that if the maximum noise levels specified in Section 6 are exceeded, the level should not be exceeded more than: (i) sixteen times in the evening between 6:00 a.m. and 10:00 p.m., and (ii) three times at night between 22:00 and 06:00.

On the other hand, the Swedish reference values for industrial noise are stricter, and moreover include a statement that "if the noise spectral contains strong tonal components, the reference levels shall be reduced by 5 dBA". As the spectral contents of multicopter UAVs typically has a high degree of tonal components, it is not unreasonable that a future reference value addressing noise from drones, will be reduced in relation to the present values for airports.

[2] FBN (Flygbullernivå) is a Swedish energetic yearly average, weighted such that during evenings the noise is rated 5 dBA higher and at night 10 dBA higher. It is very similar to L_{DEN}, but with the evening and nighttime periods starting one hour earlier.

6. Discussion

6.1. Assessment of UAVs sources for modelling purposes

The newly released EASA guidelines for *in-situ* measurement of noise from UAVs up till 600 kg is an important step for realistic assessment of drone noise. The use-case simulated above with different source character at flight and at take-off/landing would not be possible to analyse from lab test data only, e.g. with reference to EN ISO 3744 as required in the EU regulations when assessing sound power of small UAVs [24]. The EASA guidelines require measurement at hover and not at take-off and landing which is a limitation. The increased sound generations at take-off, may be estimated from *in-situ* hover data in combination with test bench measurements in which relationships torque-sound power level are determined in combination with assumptions of the vertical acceleration. For the UAV analysed, we have from test bench data that a 10% increase in thrust from the hover thrust level results in about 1 dBA increase in sound power. Such increase in thrust results in realistic vertical acceleration, lifting the UAV to 50 m in 10 seconds. Obviously, a higher climb rate would lead to more starting noise, and it is wise for operators to control the added noise at climb by applying a sensible climb rate. For modelling purposes, in addition to the overall sound levels it will be useful if also spectral data is recorded and presented as described in the newly released ISO/FDIS 5305 [28].

However, it is not judged to be practically reasonable to require directivity data for each type of UAV vehicle for the needs of simulations. For many types of UAVs, directivity patterns can be estimated based on generic directivity models as exemplified in Figure 1.

6.2. Noise maps as a tool in assessment and communication

Simulations using the SAFTu tool can provide information on ground noise exposure based on scenarios for operations. In such scenarios, droneport locations and flight paths can be evaluated and rated with respect to noise and annoyance as well as boundaries identified for air space design. Simulated data can be displayed in noise maps, showing areas subject to different $L_{A,MAX}$ levels or for UAM scenarios using $L_{A,\,EQ}$ metrics like L_{DEN}. Difference in sound levels, e.g. sound reduction between two different scenarios can also be illustrated.

The primary use of noise maps from is to optimize flight paths and operative settings, but the software can also be used as tool in training of operators and other stake holders in e.g. understanding different noise metrics and the effect of different operating conditions or “concepts of operation”. Results from the tool can also be used to assess the maximum and equivalent noise levels around a proposed UAV landing site, to benchmark sound levels at neighbouring buildings to regulative noise limits. Such results can be used in dialogue with affected citizens. From experiences with traffic alterations on existing airports, it is clear that dialogue and openness with affected citizens is essential in avoiding infected situations after the changes have been introduced [9].

Regarding integration of UAVs in urban aeras, results from SAFTu can potentially be used in combination with tools for noise from ground traffic assessment, to evaluate added annoyance in relation to existing noise sources e.g. in line with the VDI 3722 guidelines [27]. For planning of novel UAV routes in an urban context, it is desirable to account for exposure from existing noise sources for example when evaluating an UAV route along an existing road. Marginal effects accounting for the added annoyance from introduction of UAVs in urban environments can potentially be analysed using dynamic modelling methodology presented in reference [29].

7. Concluding remarks

From the sound levels calculated, we may conclude that the scenario analyzed based on fixed wing delivery UAVs, will not significantly add to noise levels in the city. Fixed wing delivery UAVs are generally fairly silent and will hardly be noticeable in relation to general city noise. In addition, the speed of the fixed wing UAVs is fairly high, such that the overhead disturbance will pass in a few seconds. On the other hand, the corresponding multicopter UAVs are substantially noisier simply because of the need for lifting the entire UAV mass during flight.

Based on the results from the use-case analyzed, one conclusion is that the Swedish air traffic reference levels [12] regarding $L_{A,max}$ measured at building façades close to a new droneport installation will govern the compliance with the noise exposure regulation rather than L_{DEN} levels (energy summation based). For the case analysed with a uniform distribution of movements over the 24 hour cycle, the number of landings at a hospital droneport must exceed

70 per day for the L_{DEN} reference levels to be exceeded assuming the $L_{A,max}$ levels is at the reference level 70 dBA The same holds true if the noise from a new droneport is assessed with respect to the Swedish reference levels for Industrial noise [12].

From simulations using measured data from a state-of-the-art delivery drone, it is found that the present Swedish $L_{A,max}$ air traffic target levels, stipulated at building façades, will not be exceeded if the droneport is located at least ca 30 m from adjacent buildings. However, in view of the highly tonal character of drone noise, it is not unlikely that future reference values may be lowered in relation to those from regular aircraft, to reflect the greater annoyance perceived by exposure to noise from drones [1],[22],[26], and also because a new kind of air-borne noise source may be experienced as intrusive, especially in environments previously unaffected by aircraft noise [1].

Simulations are widely recognized for their role in supporting well-informed decision-making. By visualization of flight routes and by graphical and aural presentation of noise impact in different scenarios, simulation tools can effectively support the planning of suitable routes and the location of droneports that will mitigate unintended and undesired consequences and increase societal acceptance of drones. Furthermore, calculation results can be integrated into various actors' processes for regulations, urban planning, traffic planning and not the least important, communication with affected citizens. In addition to noise maps, simulation results from SAFTu can be postprocessed in modern tools such as virtual reality and, if combined with sound recordings, auralization tools, to provide effective ways to inform and engage the public.

Finally, we conclude that decisions regarding drone integration made without adequate information may result in systems with unforeseen and undesirable consequences, particularly when these systems rapidly scale over time. The European Green Deal [23] includes a criterion that no people or places should be left out. This includes those residents who will be affected by the construction of new droneport infrastructure in their immediate area and noise from the associated traffic.

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