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A SPATIAL PROCESSING FRAMEWORK FOR MAPPING AREAS BENEFITING FROM URBAN MORPHOLOGY AND BUILDING DESIGN IN AIRPORT REGIONS

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ABSTRACT

In many places, ongoing urban expansion, in conjunction with higher traffic volumes, have reduced or dissolved the separation between environmental noise zones. This is specifically the case near airports, with conflicting land-use demands for housing and flight operations. Apart from zoning, aircraft noise plays no role in urban design and form studies. Serving as tall noise barriers, recent studies in a designated test street demonstrated the potential of buildings as noise barriers for reducing aircraft noise in urban contexts. Correlating sound shielding levels with the elevation angle of passing aircraft, results from the test street environment were used for mapping shielding potential areas on a regional scale. This study introduces a spatial framework combining aircraft trajectory, and land-use, geo-data to determine such areas using a geo-spatial processing methodology in QGIS. It is applied the Amsterdam Schiphol airport region as case study.The methodology determines areas affected by noise from passing aircraft at elevation angles identified as most indicative for leveraging optimal shielding by buildings. The subsequent map layers can aid urban planners in decision-making processes for further exploring the potential of urban design for mitigating aircraft noise in urban airport regions, serving further tool development for livable and healthier neighborhood design.

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1. INTRODUCTION

Prolonged exposure to aircraft noise is associated with various health risks, both physical and psychological. For example, communities close to airports report higher cardiovascular hospital admission rates [1], and worse sleep quality [2], and have an increased risk of high blood pressure [3]. Compared to other traffic noise sources, aircraft noise is perceived as more annoying, at similar L_{DEN} noise levels. To mitigate and minimize aircraft noise effects, land use planning and management constitutes a priority of the International Civil Aviation Organization's "Balanced Approach" for noise reduction around airports [4]. A consequence of this approach is a strict regulation of housing developments through environmental zoning in the proximity to flight paths, depending on air traffic movements. The boundary conditions for land use and planning are defined by noise contours, generated computationally based on standardized methods, such as Doc29, INM (Integrated Noise Model), or national equivalents such as NRM (Netherlands Regional Model) in the Netherlands. For the case of Schiphol International Airport in the Netherlands, this amounts to a total area of 203 km^2 in which new housing projects and urban area (transformation) development is mostly prohibited (LIB 4), and or, an even greater surface of 384 km^2 where area development and housing expansion is strictly regulated (LIB 5) (See Fig. 1) [5]. This has resulted in so-called 'noise landscapes' around many airports, referring to land-use patterns and spatial typologies unique for airport regions. To compromise computational overhead and model complexity, aircraft noise prediction methods rely on various assumptions for describing source, atmospheric and surface conditions. One of these assumptions is that the ground below a receiver position comprises flat surfaces, thus omitting the reflections and diffraction of sound waves in the built environment [6]. Although this approach seems acceptable valid under flat-field conditions based on annual aggregations, this is not the case for urban contexts.

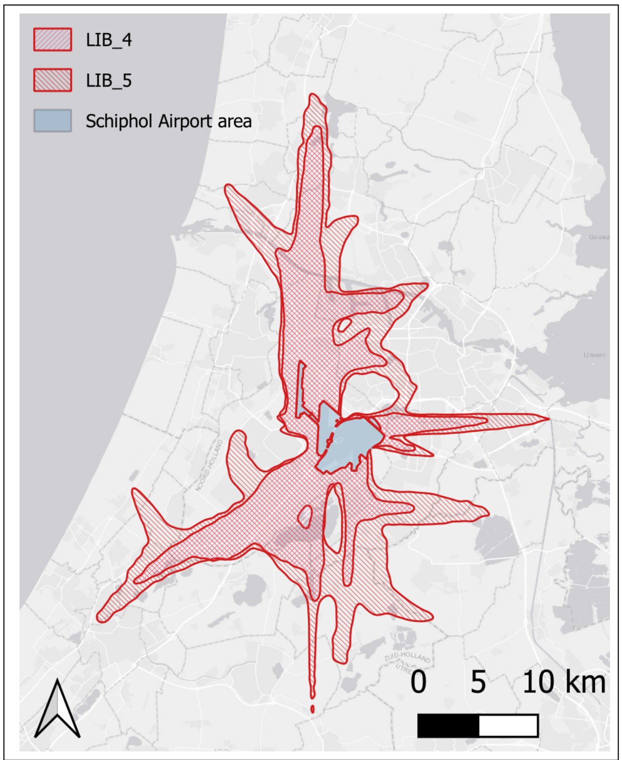

Figure 1. Areas of noise sensitive building restrictions and consideration between noise and external safety around Schiphol airport, Netherlands

Buildings, when placed parallel along flight paths, can function as noise barriers, reducing noise levels on the facade shielded from direct incident noise. This effect was investigated at the Urban Comfort Lab (abbr. UCLab) from 2022-2024, with a full-scale measurement facility consisting of 120 shipping containers arranged to recreate the urban form of three different courtyard configurations. Long-term measurements were conducted, and recorded a mean A-weighted sound exposure level (abbr. ASEL) reduction of 8.1 dB(A) between exposed and shielded building sides for two-story courtyards [7]. The addition of a slanted roof on the exposed side to reduce courtyard noise reflection effects, and a building inset on the shielded side to reduce diffraction levels, further increased the mean ASEL difference to 11.6 dB(A). These ASEL differences were measured for flights passing the facility at a mean elevation angle at closest point of passing of 37 degrees (abbr. °), with a standard deviation of ±7°.

While these findings demonstrate the potential of the use of buildings to reduce local sound levels, the integration of these effects into land use management and planning is lacking. Despite demonstrating the potential of low-rise urban canyons for aircraft noise reduction for a single test site consisting of three canyons, the potential of the UCLab results at regional scale largely remain unclear. Also, such cross-scale extrapolation at full scale of airport operations would allow for further examination of the impact of this approach, compared to the existing spatial zoning regime and described aircraft noise prediction methods. Assuming similar noise reductions for the range of elevation angles passing the UCLab, this study proposes a first assessment entailing the integration of the built environment into the strategic noise planning in airport regions.

This study presents a methodology for mapping the number of daily flyovers at elevation angles recorded in the UCLab for regions around airports using QGIS and historical ADS-B aircraft positional data as input. The methodology is then applied to a test case of Schiphol airport, for flights departing and arriving in January 2023. Finally, an exploration into the integration of the generated maps in land use planning is conducted.

The objectives of this study are defined as follows:

1. Design of a methodology that maps aircraft flyovers at defined elevation angles for airport regions.

2. Application of the methodology to aircraft arriving and departing from Schiphol airport in January 2023.

3. Examining the spatial consequences of the method in comparison with e.g. existing noise zoning and land-side aircraft noise mitigation schemes.

2. METHODOLOGY

Based on the study conducted by Lugten et al. [7], one can expect courtyard ASEL shielding effects between 8.1

dB(A) and 11.6 dB(A) for flights passing at a mean elevation angle of 37° at closest point of passing , with a standard deviation of ±7°. Within this elevation angle range, it is assumed urban canyon morphologies similar to UCLab can yield equivalent noise reduction levels between exposed and shielded building facades. This elevation angle range of 30° and 44° can be extrapolated along flight paths. The measured ASEL differences are assumed independent of ground distance [8]. Results depend accordingly on the altitude of the aircraft (see Fig 2), leading to ground areas parallel to the flight path. The areas increase in width and in distance from the ground flight path with increasing aircraft altitude. Within these two boundaries, the method presented in this paper assumes that the urban geometry akin the UCLab design is applicable and will yield comparable noise shielding effects.

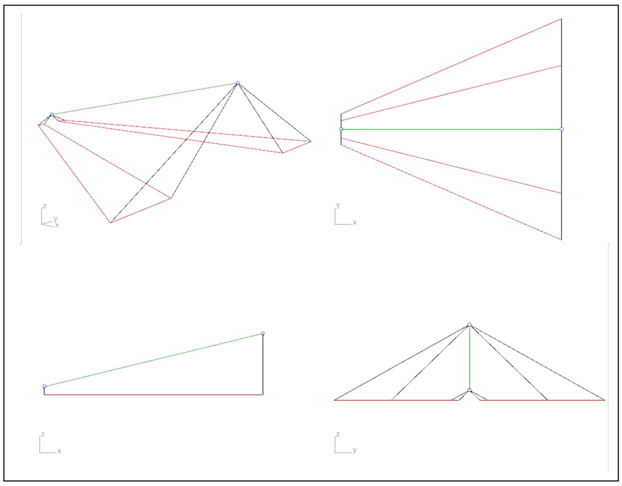

Figure 2. Flight path following a straight ascent (green) and applicable areas for noise-adaptive building (red) in perspective view (top left), top view (top right), side view (bottom right), and under flight path (bottom right)

For spatial mapping purposes, the open-source geospatial software QGIS (version 3.34) was used to create the processing framework. The methodology is generated in the graphical modeler environment, using native processing algorithms and processing scripts created using the QGIS Python Console. A graphical overview of the input, processing steps, relevant parameters, and output is shown in Figure 3. The input data is of format line .shp data. The line data contain z (altitude) variables of all vertices of each flight. The line data are fed into the model and split up into vertices. Vertices with an altitude between 50 and 1500 meters are extracted. 50 meters as a lower threshold is defined to remove flight points on the runways. The higher threshold is set to reduce computational overhead, under the assumption that aircraft passing at an altitude of 1500 m and higher do not lead to high noise exposure. Subsequently, variable width buffers are calculated for maximum and minimum elevation angles, with the width defined as altitude/tan(elevation angle). Differences between the lower and upper boundary elevation angle buffers are generated per feature and intersected with a flat end buffer., leading to ground areas parallel to the flight paths in which the aircraft passes at an elevation angle between 30° and 44°. The resulting area for a single flight is displayed in Fig. 4

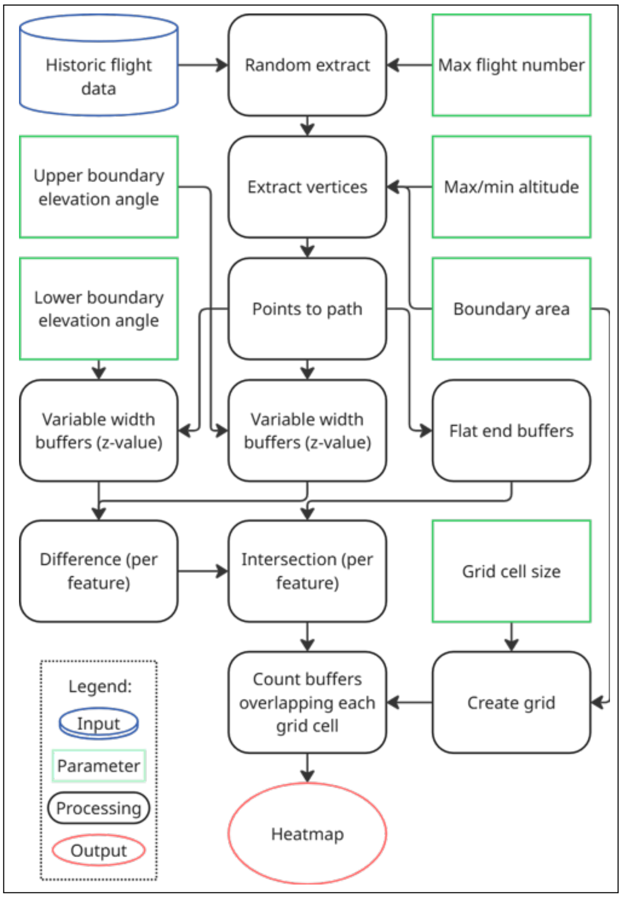

Figure 3. Geo-processing flowchart of the developed spatial framework

To map the number of flights passing locations on the

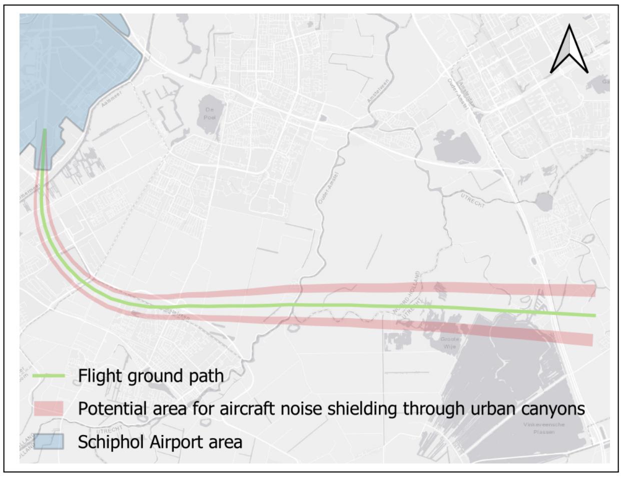

Figure 4. Flight path (green) of Flight KLM831 departing from Schiphol Airport (blue) to an altitude of 1500m on Jan 1st 2023 and altitude-dependent potential area (red)

Figure 5. Grid cell map layer displaying the number of flights passing at an elevation angle range between 30° - 44 °

ground at the defined elevation angles, a hexgrid of 200m x 200m is generated within a predefined boundary area around Schiphol airport, based on the extent of the LIB 5 layer. For each grid cell, the amount of buffers overlapping the cell are counted, creating an index of the total flights passing at an angle between 30° and 44° at closest ground distance between flight path and grid cell. The index is divided by the amount of days of the period of analysis, yielding the number of flights per day to identify areas with high daily flyover rates at elevation angles suitable for noise shielding through urban canyons. Fig 5 shows an example output of the processing methodology. Grid cells recording less than 4 flights per day are removed from the dataset for legibility.

3. AMSTERDAM SCHIPHOL AIRPORT

To test the methodology's applicability, the processing framework was applied to the region surrounding Amsterdam Schiphol airport, in the Netherlands. The line input data consist of all flights departing and arriving from Schiphol airport during January 2023, based on ADS-B radar data retrieved from Casper flight data portal, provided by the airport authority. For processing capacity reasons, for the case study presented in this paper a only half of the data was used, based on randomized selection, resulting in a total of 15545 flights. For data processing a laptop computer was used (11th Gen Intel(R) Core(TM) i7-1185G7 @ 3.00GHz with 16GB RAM), requiring a runtime of 13 hours. Figure 6 shows the resulting grid layer for the area surrounding Schiphol airport. The main arrival and departure routes are visible. Arrivals can be distinguished from departures, characterized by straighter and narrower surface boundaries due to fixed arrival trajectories. In contrast, climb rates are steeper for departures compared to arrivals, resulting in 'shorter' areas per flight path, which are also more curved and less fixed.

4. GEO-SPATIAL AND LAND-USE ANALYSES

Apart from the area plots, the density maps presented in the previous section can be combined with other spatial datasets, e.g. related to the spatial distribution of complaints, building stock and facade insulation data, and/or planned location for housing development or urban retrofitting.

For example, Figure 7 combines the density grid with residential land use and planned residential areas layers and with Dutch Spatial Legislation for Airport Land-side Management layers LIB 4 and LIB 5 [?]. Within LIB 4, housing projects and urban area (transformation) development is mostly prohibited. In LIB 5, area development and housing expansion is strictly regulated. These maps indicate which areas might benefit from the findings as introduced in this article. One such (illustrative) exam-

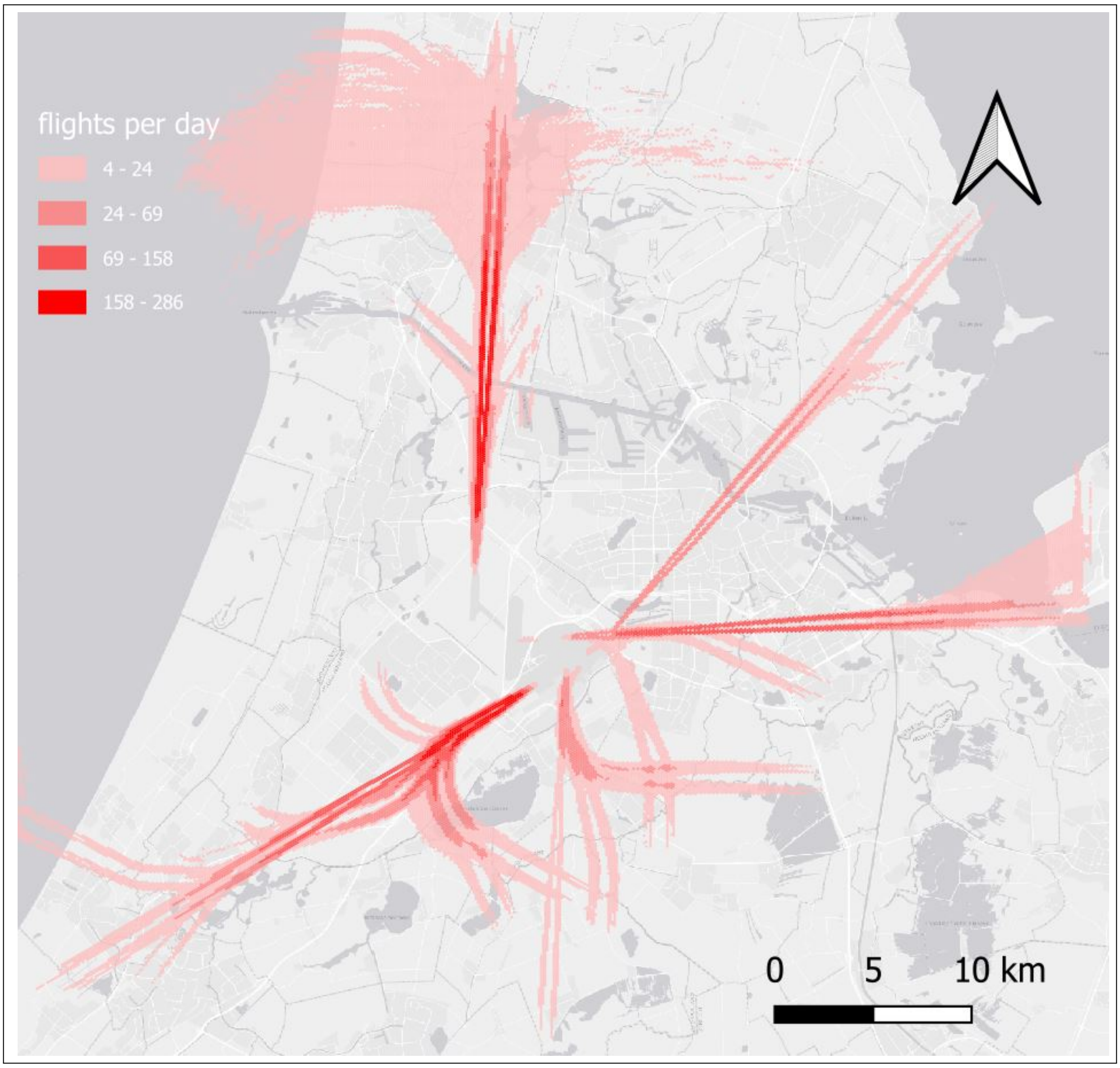

Figure 6. Number of flights passing at an elevation angle range between 30° and 44° per grid cell for flights to and from Schiphol airport in January 2023

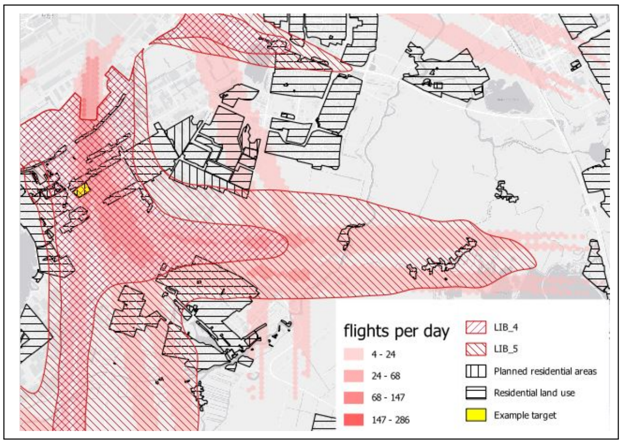

Figure 7. Overlay of spatial processing output, LIB 4 and LIB 5 zones, (planned) residential land use and spatial processing output, with high potential example target

ple area is highlighted in Figure 7, indicating a planned residential development in the LIB 4 zone, with a high frequency of flyovers within the elevation range allowing the use of urban form for noise shielding. Thereby these maps could aid spatial planners, urban designers - but also airport and governmental authorities - in determining for which locations additional 'urban and architectural form' oriented measured could be investigated and considered. To further pinpoint areas of heightened interest, grid density maps can be combined with noise annoyance data. Figure 8 shows flight paths and the percentage of highly annoyed inhabitants by aircraft noise per neighborhood. Neighborhood shape files are sourced from the Dutch national Geo-registry [9], the noise annoyance per neighborhood is sourced from the RIVM open StatLine data portal [10] . Although higher noise levels largely coincide with higher noise annoyance, it is advisable to take into account both where data allows.

5. CONCLUSIONS

In this article a spatial analysis framework is presented, aimed at identifying areas in which building and urban design interventions may contribute to aircraft noise attenuation in urban contexts. Using aircraft flight data, the framework generates a grid overlay to extrapolate small-scale findings to the mesoscale airport regions. The method calculates the number of aircraft passing at ele-

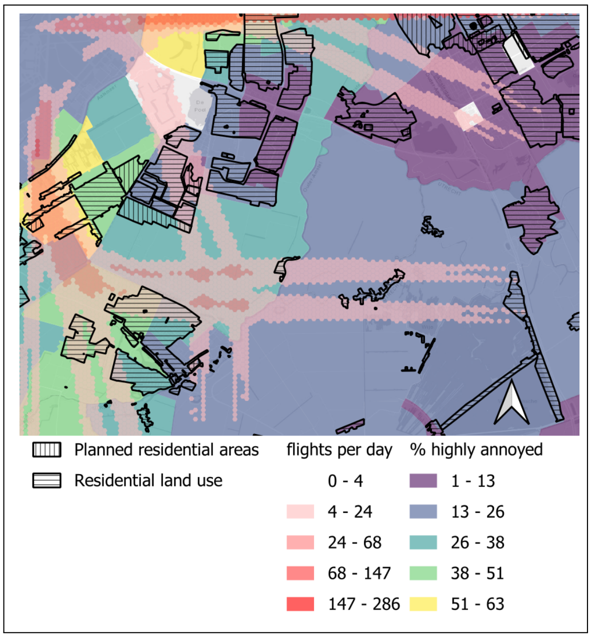

Figure 8. Overlay of spatial processing output, (planned) residential land use areas, and percentage of inhabitants highly annoyed by aircraft noise per neighborhood

vation angles fitting the conditions for building-induced shielding effects between 8.1 dB(A) and 11.6 dB(A) derived from in-situ measurements in a test canyon for each grid cell. This added layer of spatial information presents areas which meet similar conditions, based on cross-scalar spatial extrapolation of measurement results. The outcomes are useful for e.g. identifying where urban design might be of further interest for aircraft noise mitigation in existing and planned housing and area developments around airports. The method takes into account e.g. aforementioned elevation angles, derived from flight data obtained for a test location in which extensive measurements were carried out. Factors including variations of atmospheric refraction over longer distances were omitted for this method. Sound shielding variances arising from weather variables could be studied as part of future research. While this methodology delivers robust results for the analyzed area and time-frame, extended aggregation for the time period of a full representative year is envisioned. This time-frame will allow for more accurate representation of the flight distribution arriving to, and departing, from Schiphol airport.

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