Drone Infrastructures Planning on Large-Scale for Passenger Transport

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1. Main body

In the geomatics field, UAVs (Unmanned Aerial Vehicles), commonly known as "drones", are typically considered data acquisition tools for advanced analysis. However, technological innovations are expanding their potential uses, such as for transporting goods and people. This evolution provides opportunities to integrate drones into mobility systems, with significant territorial implications at the local level. Unlike traditional aviation, where the impact is limited to airports and along the approach and departure paths, drone infrastructures like vertiports - takeoff and landing points for drones - and corridors - the future "sky roads" - will spread across the territory. This requires the involvement of authorities at all levels in decision-making processes to identify the most suitable areas (Piano Strategico Nazionale AAM (2021-2030), 2022). This approach will need to consider various relevant factors, such as safety (e.g., risk of falling to the ground), social acceptance (e.g., noise, privacy), and accessibility (e.g., rapid connectivity with existing infrastructure). Each factor should be evaluated according to current regulations; for instance, for noise, it will be necessary to verify that drone sound emissions do not exceed legally permitted limits. The development of a market involving broader and more diversified drone use will demand a complex regulatory framework (Barrado et al., 2020). Currently, regulations are primarily developed for recreational and technical use, with rules that impose restrictions on weight, size, speed, and minimum technological features of the aircraft.

Worldwide, various organizations are working on defining norms for these infrastructures, flight management phases, and drone technical specifications. In Europe, the main players are EASA (European Union Aviation Safety Agency), EUROCONTROL, and the European Commission, which, through the SESAR (Single European Sky ATM Research) program (Bolić & Ravenhill, 2021), contribute to developing the DES ("Digital European Sky," 2020). The goal is to automate all flights to realize the Single European Sky (SES), seeking to unify EU airspaces. Although in the future all vehicles will share the same airspace, the one currently reserved for drones is called U-space. SESAR funds projects aimed at developing and testing innovative solutions to be integrated into the aviation system to achieve the DES.

This work explores the main factors useful for identifying suitable areas for both vertiports and corridors. The idea of the author is to transform regulations and other relevant factors for infrastructure planning into representative GIS raster layers, classified on a scale from suitability to absolute unsuitability, and then synthesize them into a map through multi-criteria analysis (Figure 5) (Cunietti et al., 2023). It is important to note that not all regulations may be fully met; therefore, this map will allow for the identification of areas with the least impact. Once suitable areas are outlined, relevant authorities should, where possible, define measures to mitigate any residual issues. If addressing them is unfeasible, the area should be excluded.

This approach, part of a doctoral project, intends to provide a simple process to support local authorities, who often lack tools for advanced analysis. It facilitates an intuitive understanding of the impacts of such infrastructures on their territories, thereby supporting the decision-making process. Several layers have been developed, but for necessity, only three are presented. A differentiation in the analysis type was also considered: the extra-urban environment, analyzed in Emilia-Romagna, Italy, and the urban environment, focused on Valencia, Spain. The results presented are based on the latter and focus on a passenger transport drone.

The first layer locates areas where an additional positioning level beyond GNSS can be maintained, as required by safety regulations. This is achieved by leveraging 5G antennas from mobile networks, ensuring an acceptable margin of error. Coordinates and antenna technological characteristics were extracted from a Spanish ministerial database (Figure 1). For each pixel of a 50 m resolution raster covering the metropolitan area, the positioning error was calculated using the Cramér-Rao Lower Bound (CRLB), simulating a drone flying at 150 meters (Figures 2 and 3). Initially, a DSM (Digital Surface Model) was used to identify visible antennas, excluding those obstructed by obstacles. Subsequently, an algorithm selected optimal antenna combinations to minimize localization error using CRLB (Figure 2), employing multilateration (MLAT) techniques based on Time-Difference-of-Arrival (TDOA) measurements (Galati et al., 2012). The error acceptability will depend on the positioning requirements of the drone, according to the flight environment.

The second layer establishes acoustic respect zones in urban areas, calculating the minimum distance necessary for drones to comply with noise limits near specific land uses. Integrating urban planning regulations, it defines how far drones can operate from sensitive areas, such as residential, hospitals or school zones. This is achieved through a regression equation based on the drone weight that estimates sound levels (Schäffer et al., 2021). Useful for ensuring drone integration while maintaining urban acoustic comfort and quality of life, the method was used at the regional level in Emilia-Romagna and subsequently applied to Valencia (Figure 3). The same was done with the next.

The third layer estimates the potential number of people impacted within each pixel, based on its area as determined by resolution, using the Specific Operations Risk Assessment (SORA) methodology as outlined in Annex F (JARUS Guidelines on SORA Annex F Theoretical Basis for Ground Risk Classification and Mitigation, 2024). This layer calculates a fatality rate by correlating factors such as population density, terminal velocity, and impact energy with specific drone parameters, including mass (900 kg), speed (30.56 m/s), and a standard altitude (150 m). An additional layer applies mitigation based on land uses, calculated using Sentinel-2 imagery to assign exposure factors, enhancing risk accuracy (Figure 4).

Once the multi-criteria map is obtained by overlapping all layers, it is compared with known interchange nodes from existing mobility plans. Vertiports, which serve as corridor nodes and as transfer points with other modes of transport, are then selected from the map in the areas identified as most suitable. Subsequently, the same map is used to determine routes with the lowest risk for connecting the nodes. For this phase, the Least Cost Path method is applied (Figure 5).

2. Illustrations

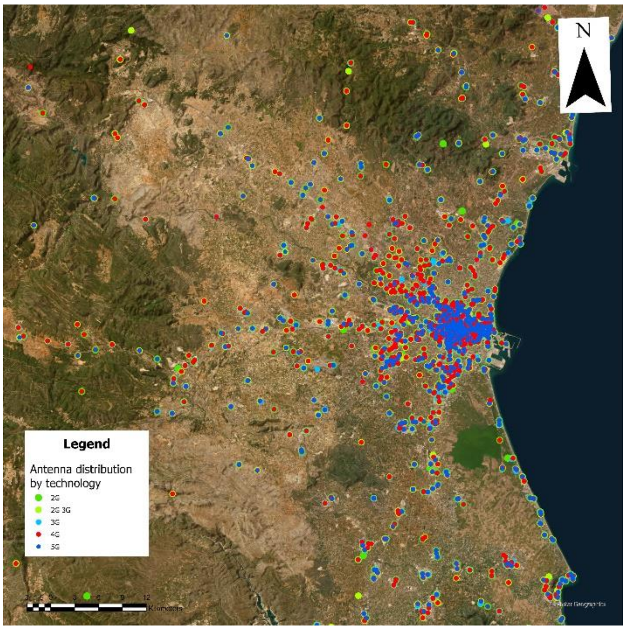

Figure 1. Antenna distribution by technology in the metropolitan area of Valencia

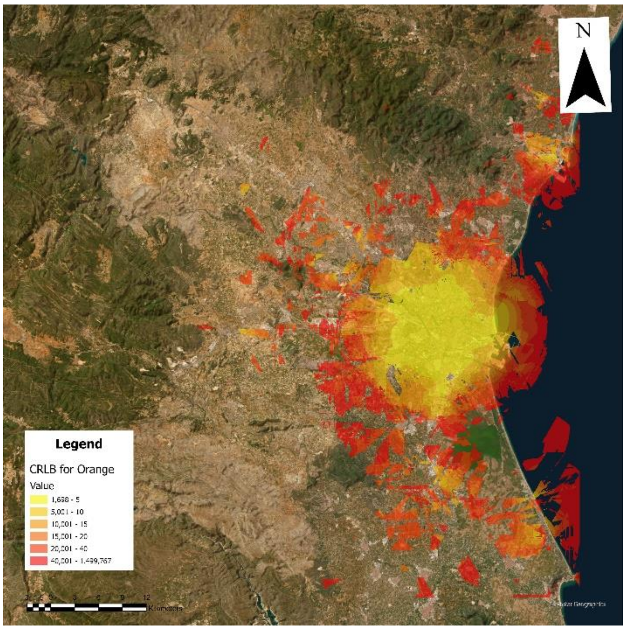

Figure 2. CRLB Calculation for Orange

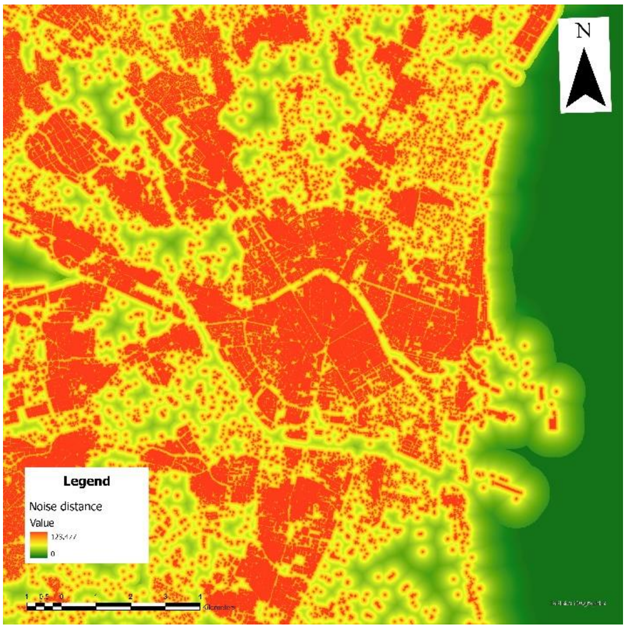

Figure 3. Noise emission

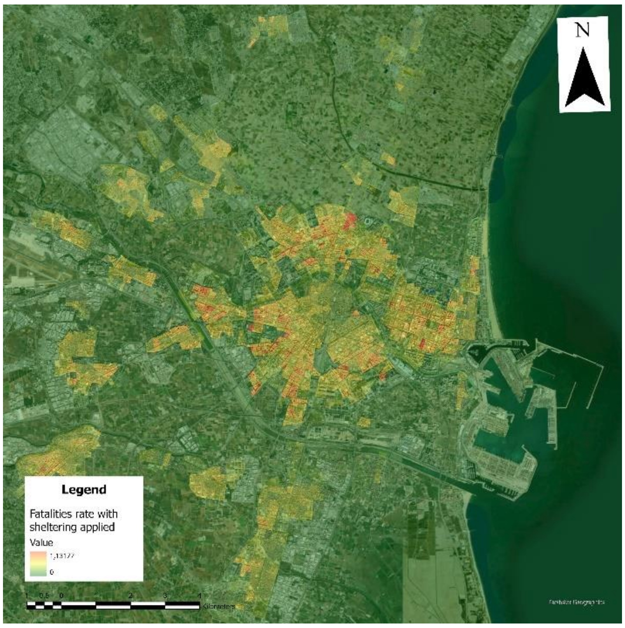

Figure 4. Fatalities rate with sheltering applied

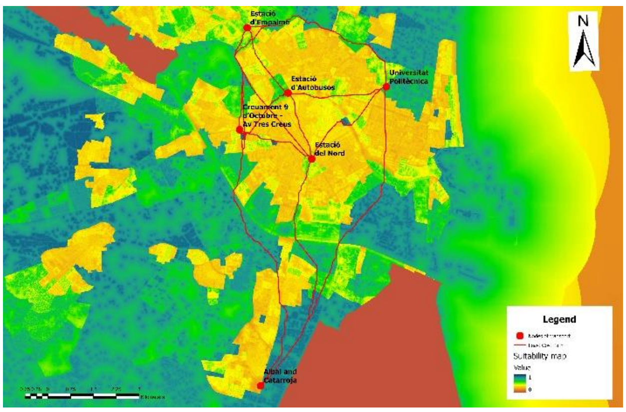

Figure 5. Multi-Criteria Analysis Calculation for a Passenger Transport Drone

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