

Integration of Drones in the Health System: Key Areas for Territorial Deployment

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GLOSSARY

ABS	Basic Health Area
EAP	Primary Care Team
AESA	Spanish Aviation Safety Agency
AGL	Above Ground Level
ARC	Air Risk Class
BVLOS	Beyond Visual Line of Sight: operations beyond visual line of sight
°C	Unit of temperature, degrees Celsius
CAP	Primary Care Centre
CatSalut	Catalan Health Service
CO₂	Carbon dioxide
ConOps	Carbon of Operations
CL	Local Clinic
CTR	Control Traffic Region: air traffic control zone
CUAP	Primary Care Emergency Centre
Dron	Unmanned and reusable aircraft capable of operating with a greater or lesser degree of autonomy, either following remote pilot instructions or pre-programmed commands
EASA	European Union Aviation Safety Agency
EDT	Aminopolycarboxylic acid, the most widely used chelating agent in healthcare

GLOSSARY

eVTOL	Vertical Take-Off and Landing Electric Aircraft: electric aircraft capable of vertical take-off and landing
ft	Unit of measurement (1 ft = 0.3048 m)
GRC	Ground Risk Class
GSS	Public company Gestió de Serveis Sanitaris of the Catalan Health Service
inhab./km²	Population density: average number of inhabitants per square kilometre in a given territory
IAM	Innovative Air Mobility
ICGC	Cartographic and Geological Institute of Catalonia
ICS	Catalan Health Institute
IDE	Statiscal Institute of Catalonia
Infrastructure for UAS	Infrastructure or areas designated for UAS take-off and landing operations, including those used exclusively for air displays, sports, recreational or competition activities involving aircraft with a maximum take-off mass exceeding 150 kilograms
JARUS	Joint Authorities for Rulemaking on Unmanned Systems: international group of experts, aviation authorities and regional aviation safety organisations that develop recommendations for the safe operation of unmanned aircraft systems
kg	Kilogram
km	Kilometre
km²	Square Kilometres

GLOSSARY

LUC	Light UAS operator Certificate
m/s	Metres per
MTOM	Maximum Take-Off Mass
OSOs	Operational Safety Objectives
PDRA	Predefined Risk Assessment
RD	Royal decret
RS	Health region
SAIL	Specific Assurance Integrity Level
SIG	Geographic Information System
SISCAT	Comprehensive Public Health System of Catalonia
SORA	Specific Operations Risk Assessment
U-Space	Set of specific services and procedures designed to ensure safe and efficient access to airspace for a large number of drones
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System

GLOSSARY

Vertiport

Term formed by acronym from the words “vertical” and “port”. It is an area of land or water, or a structure, used or intended to be used for the landing and take-off of VTOL aircraft

VLOS

Visual Line of Sight: operations within visual line of sight

VTOL

Vertical Take-off and Landing

1.

Introduction

This document presents an analysis of the feasibility of integrating drones into the logistics operations of public hospitals within the SISCAT and across the Catalan territory. The aim of this analysis is to identify the centres and areas with the greatest short-term feasibility potential for deploying healthcare logistics routes using drones. This study has been led and produced by the TIC Salut i Social Foundation as part of its work in analysing and promoting the use of emerging technologies in the healthcare sector.

The study on the use of drone technology in the health system began in 2023. Since then, three reports and one infographic have been published. Two of the reports are based on proof-of-concept trials and clinical studies focused on validating the transport of biological samples, while the third provides a general analysis of the technology.

The report *Study on the State of Drone Integration in the Health System* (Abdón Giménez et al., 2024), prepared by the TIC Salut i Social Foundation, highlighted that this technology was beginning to be integrated into new healthcare processes. That initial report emphasised the potential of drones to make healthcare more efficient, accessible and inclusive, with successful examples both in Catalonia and internationally.

Building on regulatory progress, operational developments and successful proof-of-concept trials, the need has been identified to determine the most suitable areas in Catalonia for carrying out scalable real-world trials and operations. The objective is to advance the integration of drones into the health system in areas where operations are technically and logistically viable and where the technology can generate the greatest possible healthcare and territorial impact.

This work forms part of the continuation of the mandate received by the TIC Salut i Social Foundation from the Department of Health to integrate this technology into the healthcare sector and to collaborate with a broad range of organisations within the Catalan health system and the drone ecosystem: the Emergency Medical System (SEM), the Catalan Health Institute (ICS), Gestió de Serveis Sanitaris (GSS), the Sant Hospital Foundation of La Seu d'Urgell, the Digital Catalonia Alliance (DCA), the Department of Territory, Housing and

Ecological Transition, the BCN Drone Center and Biomedical Logistics.

The participation of these stakeholders reflects a shared commitment to promoting the responsible, safe and innovative use of drones in healthcare and to laying the foundations for their gradual integration into the Catalan health system. All these entities have worked together under the coordination of the TIC Salut i Social Foundation to produce this report.

The operational analysis has been coordinated by the operator BCN Drone Center (CATUAV), a company specialising in drone operations, and the analysis of the areas has been carried out with the collaboration of the DCA, an organisation with expertise in drone technology and a key reference point in the sector in Catalonia. The Emergency Medical Service (SEM), the operator of the health system's heliports, has also participated. The Department of Territory and the company Biomedical Logistics have contributed to the territorial and infrastructure analysis. Finally, healthcare entities such as ICS and GSS have participated in analysing the care delivery dimension.

1.1 Context

In February 2023, the TIC Salut i Social Foundation received a mandate from the Innovation Committee of the Department of Health to promote the integration of drone technology within the SISCAT. To this end, a drone working group was established, bringing together various healthcare organisations, employers' associations, the Emergency Medical Service and other stakeholders from the drone sector in order to define the lines of work and the strategy for integrating this technology. The following objectives were established: to identify use cases applicable to drones, to identify the requirements for implementing drone-based solutions in healthcare, and to create healthcare projects involving drones.

Once the objectives had been defined, three main areas of work were established for the integration of drones in healthcare: logistics, emergencies and care delivery. This document focuses on the first of these areas.

Over the past two years, the TIC Salut i Social Foundation has worked to analyse the potential of this technology to transform healthcare logistics and improve system efficiency. The initial experiences have been pilot trials for the transport of biological samples in the Garrotxa area and in the northern metropolitan health region (Metro Nord), which have demonstrated the technical and clinical feasibility of this logistics model and have achieved reductions in transport time and CO₂ emissions, as well as improvements in service quality (Abdón Giménez et al., 2025; Gallinat Muñoz et al., 2024).

The first proof of concept was developed in Garrotxa, in the Girona health region, with the aim of exploring the transport of biological samples by drone, mainly blood but also other types (such as serum, EDTA, citrate, faeces, spontaneous urine and 24-hour urine). The results were satisfactory, both in terms of the pre-analytical quality of the samples and service efficiency. Transport time was reduced by 43% (4 minutes over 1.7 km, compared to the usual 7 minutes by road), and CO₂ emissions were reduced by 80.4% (Gallinat Muñoz et al., 2024).

The pilot trial in the Metro Nord area expanded the scenario to a suburban context, with flights from northern Barcelona and Vallès Oriental to the Metropolitan North Clinical Laboratory (LCMN) located at Germans Trias i Pujol Hospital. This project made it possible to address additional challenges such as managing flight permissions and coordinating airspace in more densely populated areas, while also expanding the evaluation of sample quality through a clinical study. The results once again confirmed the efficiency of drone transport, with a 72.3% reduction in transport time per kilometre and a 99.2% reduction in CO₂ emissions, while maintaining sample quality within clinically acceptable parameters (Abdón Giménez et al., 2025).

Both experiences demonstrate the usefulness of drones for transporting biological samples and highlight their viability not only in rural environments but also in suburban settings. These experiences underline the significant potential of drone transport to improve accessibility, efficiency and the quality of healthcare delivery, particularly in territories facing logistical challenges. To move towards effective integration into the health system, it

will be necessary to continue testing, optimising and validating this model in new real-world scenarios.

Despite these advances, the pilot trials carried out to date have been conducted over short periods (approximately two weeks), which limits the ability to assess their real long-term impact. It is therefore necessary to define stable and safe testing areas where drone operations are as viable as possible and aligned with the needs of SISCAT care pathways and the territory.

In this regard, it should be noted that SISCAT primary and hospital care consists of an extensive territorial network that includes 70 hospitals, 437 primary care centres (CAP), 32 primary care emergency centres (CUAP) and 730 local clinics (CL), distributed heterogeneously across the territory (according to data from the Department of Health). This complex and diverse structure shapes both logistical needs and opportunities for implementing drone routes.

This new report analyses indicators such as aerial and ground risk, population density, road and hospital infrastructure, and regulatory and safety requirements in order to determine which territories and hospitals in Catalonia could benefit most from the progressive implementation of drone flights within the health system.

Ultimately, the aim is to lay the foundations for the strategic planning of drone deployment within the health system, adopting an integrated approach that takes into account clinical benefits, operational feasibility and system sustainability in the medium and long term.

1.2 Objectives

Main objective

- To analyse the feasibility of implementing drone flights across all hospitals in Catalonia, identifying those regions and centres that offer the best conditions for establishing testing areas and future operational deployments.

Secondary objectives

- To identify areas with simpler and safer operations, where aerial and ground risk is low and regulatory compliance is more manageable.
- To identify areas where the use of drones provides greater added value compared to traditional road transport in terms of response time, accessibility or environmental efficiency.
- To analyse the availability and quality of existing infrastructure (roads, hospital access points, take-off/landing areas, connection with emergency services) to ensure the practical feasibility and sustainability of the service.
- To provide strategic recommendations for future pilot trials and deployments aligned with the current regulatory framework and with upcoming developments in the SORA 2.5 methodology.

From an operational perspective, an unmanned aircraft with a maximum take-off mass (MTOM) of less than 25 kg will be considered, so that it falls within operations in the specific category (see Annex I), with characteristic dimensions of up to 3 metres, a maximum speed below 35 m/s, and redundancy in communication systems. These are the characteristics of the operational scenario in which the most advanced drones on the market can operate.

1.3 Scope

This report focuses on the use of drones for healthcare logistics, specifically the transport of biological samples (blood, faeces, urine and pathological anatomy) between primary care (CAP, CUAP and CL) and hospital care.

The analysis, which covers all hospitals in Catalonia, aims to identify which areas and centres offer the most favourable conditions for conducting pilot trials and for future operational deployment.

The study includes the assessment of operational risk, population density, road and hospital infrastructure, orography and the current regulatory framework. Other applications of drones within the health system, such as the transport of organs and tissues and blood components (red blood cells, platelets and other types of biological samples), or their use in emergency response and care delivery applications (on-site emergencies, surveillance or disaster support), fall outside the scope of this document, although their relevance and potential for future work are acknowledged.

2.

Regulatory Framework

This section presents the regulatory framework that establishes the technical and legal conditions for the use of drones in the transport of samples and pharmaceutical products addressed in this report. It includes the applicable regulations at both European and national level, the risk assessment methodology (SORA), as well as the specific conditions and regulations relating to the safe transport of biological samples and pharmaceutical products.

2.1 Regulations Applicable to Unmanned Systems

In the healthcare context, drones can be used for different applications, such as healthcare logistics. For the proper integration of unmanned systems in the healthcare sector, it is essential to ensure that operations are carried out within a legal framework that guarantees public safety, the protection of privacy and service reliability. In this regard, as indicated in previous reports, from a legal perspective drones are considered aircraft. For this reason, drones are subject to aviation regulations governing them at both European and national level. This classification implies that operations involving unmanned aircraft systems must comply with strict requirements in terms of safety, liability, pilot training, technical certification, data protection, etc.

This chapter provides a summary of the regulatory framework applicable to drones and unmanned systems:

- At the European level, the regulatory framework is based on **Commission Implementing Regulation (EU) 2019/947 and Delegated Regulation (EU) 2019/945**. These regulations provide the common legal basis applicable to all Member States of the European Union, including conditions of use, operational categories based on risk, and design and manufacturing requirements for UAS.
- At national level, Spain has complemented this framework with **Royal Decree 517/2024**, which regulates civil activities not covered by the European regime and introduces specific measures relating to

zoning, training and operational safety. It also includes the concept of Infrastructure for UAS use, referring to infrastructure or areas designated for UAS take-off and landing operations, including those used exclusively for air displays, sports, recreational or competitive activities involving aircraft with a maximum take-off mass exceeding 150 kg.

With the aim of facilitating the safe, efficient and scalable integration of drones into airspace, the European Union has developed the concept of U-Space: a set of systems, services and specific procedures designed to enable safe, efficient and affordable access to airspace for numerous or complex UAS operations, based on highly digitalised and automated technological developments. U-Space services provide significant added value, particularly in congested areas or those with high levels of air traffic, such as areas near aerodromes, vertiports and UAS infrastructure. For this reason, the deployment of U-Space is planned in designated areas that meet these characteristics.

In the healthcare sector, the deployment of U-Space opens the door to complex operations such as automated transport, while ensuring operational safety and coexistence with manned aviation. U-Space, like unmanned systems, has its own specific regulatory framework aimed at consolidating a “Single European Sky”.

- This system, defined in **Commission Implementing Regulation (EU) 2021/664**, establishes automated digital services to coordinate drone operations in low-altitude airspace, particularly in urban or densely populated environments. Commission Implementing Regulation (EU) 2021/665 and Commission Implementing Regulation (EU) 2021/666 complement the European U-Space regulatory framework.
- In Spain, **Royal Decree 517/2024** incorporates this European framework and develops its territorial application, including U-Space zoning and requirements for service providers.

Further details of these regulations can be consulted on the websites of the European Union Aviation Safety Agency (EASA) and the Spanish Aviation Safety Agency (AESA).

2.1.1 Other Regulations Applicable to UAS

In addition to the regulations referenced above, it should be noted that unmanned systems are also subject to aviation regulations and other related legal frameworks. Below is a non-exhaustive list of some of the most relevant reference regulations:

- Convention on International Civil Aviation (Chicago Convention, 1944)
- Law 48/1960 of 21 July on Air Navigation
- Law 21/2003 of 7 July on Air Safety
- Law 8/2025 of 29 September amending Law 48/1960 on Air Navigation and Law 21/2003 on Air Safety mentioned above. The new law incorporates drones into the legal framework governing aeronautical personnel and updates the sanctioning regime for non-compliance, both in drone operations and in the transport of dangerous goods
- Royal Decree 1180/2018 on Air Regulations, Royal Decree 123/2017 on the use of the radioelectric public domain (RUER), Order ETD/625/2023 approving the National Frequency Allocation Table
- Directive 2014/53/EU (Radio Equipment Directive – RED)
- Directive 2014/30/EU (Electromagnetic Compatibility – EMC)
- Directive 2014/35/EU (Low Voltage Directive – LVD)
- Organic Law 1/1982 on the protection of honour, personal and family privacy and self-image
- Regulation (EU) 2016/679 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data
- Organic Law 3/2018 on personal data protection and guarantee of digital rights, Legal report of the Spanish Data Protection Agency based on Opinion 01/2015 on privacy and data protection in relation to unmanned aircraft
- Organic Law 4/2015 on the protection of public security
- Law 39/2015 on the common administrative procedure of public administrations

In accordance with these regulations, it is clear that the legal framework applicable to unmanned systems extends well beyond aviation law, incorporating multiple related

regulatory domains. These regulations address key aspects that must be considered in the development and operation of drones and other unmanned aircraft.

2.1.2 Sector-Specific Regulations for Healthcare Transport

As indicated above, the use of drones is also subject to compliance with sector-specific regulations. In the present context, the transport of samples and pharmaceutical products, particular attention should be paid to regulations governing:

1. Transport of biological samples: blood, urine and other biological specimens
2. Transport of small consignments: documentation, medical equipment, instruments or other necessary materials
3. Pharmaceutical transport: medicines
4. Transport of sterilisation materials: routes before and after sterilisation
5. Use of refrigerated containers with integrated traceability

For the transport of biological samples and medicines, the following sector-specific regulations shall apply on a supplementary, non-exhaustive basis to these contracts, depending on the activity to be carried out:

- WHO Guidance on Regulations for the Transport of Infectious Substances (2021–2022).
- European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR, 2023). The ADR also applies to domestic transport within the EU under Directive 2008/68/EC. This agreement classifies substances that may contain biological agents as Class 6.2 and establishes that, in accordance with packing instructions 620 and 650, packaging must consist of three layers:

- * Leak-proof primary receptacle containing the sample
- * Leak-proof secondary container with absorbent material
- * Outer packaging to protect against external influences

- Law 16/1987, of 30 July, on the organisation of land transport and its implementing regulations
- Law 29/2003, of 8 October, on the improvement of competition conditions and safety in the road transport market which partially amends Law 16/1987, of 30 July, on the organisation of land transport
- Law 15/2009, of 11 November, on the contract for the carriage of goods by land
- Law 24/1998, of 13 July, on the Universal Postal Service and the Liberalisation of Postal Services and subsequent amendments, including Law 43/2010, of 30 December, on the Universal Postal Service and users' rights and the postal market
- Royal Decree 551/2006, of 5 May, regulating the transport of dangerous goods by road within Spanish territory
- Royal Decree 1211/1990 and Regulation of the Law on the Organisation of Land Transport Law 31/1995, of 8 November, on the prevention of occupational risks
- Royal Decree 1215/1997, of 18 July, establishing the minimum health and safety requirements for the use of work equipment by workers
- Royal Decree 664/1997, of 12 May, on the protection of workers against risks related to exposure to biological agents at work

Within the healthcare field, the Directorate-General for Healthcare Resources of the Department of Health sets out the guidelines on the appropriate conditions for the transport of diagnostic samples in its document "Requirements for the transport of diagnostic samples to ensure the stability of their biological properties", which is mandatory for the contractor (Department of Health & Generalitat de Catalunya, n.d.). The Department of Health determines the requirements that must be met by the containers used for the transport of samples, as specified in the technical specifications. These requirements establish that the containers must maintain a temperature between 8 °C and 21 °C using the materials provided by the company and, additionally, must be capable of maintaining temperatures between 2 °C and 8 °C for refrigerated samples or between -18 °C and +2 °C in exceptional cases of frozen samples, during the planned transport time, which is between 90 and 120 minutes.

With regard to the physical protection of the samples, the regulations establish that the carrier must ensure that they do not suffer impacts or are subjected to conditions that could alter their quality. This includes avoiding knocks, vibrations, pressure changes or inappropriate exposure. Proper packaging and the use of resistant and appropriately labelled outer containers must also be ensured. These measures guarantee that the samples arrive in optimal conditions for diagnosis.

2.2 Risk assessment analysis in UAS operations

The effective integration of unmanned aircraft systems (UAS) into the healthcare logistics chain represents a disruptive technological advancement, but entails critical operational challenges that current regulations address from a comprehensive safety perspective. Given that the transport of pharmaceutical material and biological samples requires long-range operations or operations beyond visual line of sight (BVLOS) and in complex environments, European regulation moves away from a rigid model to adopt a risk-based approach. According to Implementing Regulation (EU) 2019/947, there are three categories of operation: open, specific and certified.

Drone operations for the transport of biological samples and pharmaceutical material fall within the specific category of medium operational risk, which includes:

- Flights beyond visual line of sight (BVLOS)
- Flights with drones with a maximum take-off mass (MTOM) of more than 25 kg
- Flights above 120 metres above ground level
- Operations in which material is dropped
- Operations with drones in an urban environment with an MTOM greater than 4 kg or without a class identification label

Implementing Regulation (EU) 2019/947 specifies that, in order to operate in the specific category, UAS operators must:

1. Submit a declaration stating that the operation complies with a standard scenario. These types of operations include a list of predefined mitigation measures that the operator undertakes to comply with.
2. Apply for and obtain an operational authorisation issued by the competent authority. In the case of Spain, the competent authority responsible for processing and issuing these applications is the State Aviation Safety Agency (AESA). The application for operational authorisation is based on the risk assessment of the operation. The conditions of this application vary depending on whether it complies with a PDRA (Predefined Risk Assessment) or not.
3. Hold a Light UAS Operator Certificate (LUC). This certificate exempts the operator from having to obtain an operational authorisation or submit an operational declaration in order to carry out the operation.

According to the parameters defined by the regulation, UAS operations for the transport of samples and pharmaceuticals between hospitals require either an operational authorisation or that the operator holds an LUC. Within this framework, the SORA (Specific Operations Risk Assessment) methodology, developed by JARUS (Joint Authorities for Rulemaking on Unmanned Systems) and adopted by EASA and AESA, is established as the reference standard, as it is an analytical process that allows risks on the ground and in the air to be quantified in order to determine the necessary safety measures. SORA acts as a structured and procedural safety requirement that ensures that healthcare transport operations and other comparable operations are compatible with the integrity of the airspace and the safety of people on the ground. On 29 September 2025, EASA published version 2.5 of SORA as a valid methodology for risk assessment in specific category operations. This version introduces significant improvements for operations in healthcare and urban environments, as it facilitates understanding and application by operators and ensures a more proportionate and transparent risk assessment framework.

These developments open the door to operating with greater legal and technical certainty in healthcare centres and hospitals, provided that

the established requirements are met, as they allow:

- To identify which hospital areas present lower ground and air risk and, therefore, a more manageable SAIL
- To define the necessary mitigation measures for each environment (flight routes, schedules, protocols with SEM and ATC, etc.)
- To establish pilot test planning more aligned with the current regulatory framework

The next chapter presents the SORA methodology in more detail and explains how to apply it to the transport of samples and pharmaceuticals between hospitals using drones. SORA analysis and the calculation of SAIL are the fundamental tools to ensure that drone flights within the healthcare system are conducted with safety, regulatory feasibility and operational sustainability.

2.2.1 SORA Methodology (Specific Operations Risk Assessment)

The SORA 2.5 methodology consists of applying an iterative process to holistically assess the safety of the operation based on the aircraft, the environment and the type of operation.

To begin using it, a comprehensive definition of the Concept of Operations (ConOps) is required. In the context of healthcare logistics transport, this involves describing not only the technical characteristics of the drone (dimensions, kinetic energy, navigation systems), but also the operational design:

- **Flight volume:** precise definition of the geography of the route between healthcare centres
- **Temporal aspects:** flight schedules (day/night)
- **Nature of the flight:** automatic Beyond Visual Line of Sight (BVLOS) operation

With regard to risk assessment, SORA 2.5 measures risk along two main axes:

- Ground risk (GRC, Ground Risk Class):
- determines the intrinsic risk of the operation
- of striking an uninvolved person in the event of an incident or drone crash during the operation. The estimation of ground risk is carried out based on two parameters:

* The kinetic energy of the aircraft, which depends on the maximum characteristic dimensions and the maximum speed of the drone used in the operation (Table 1)

* The operational scenario, which is defined by the population density within the operational volume and the ground risk buffer

Table 1 shows the methodology for calculating intrinsic ground risk as defined in SORA 2.5. This table includes detailed information on the aircraft and links it to the population density (persons/km²) in the area of operation. SORA 2.5 also includes a table with qualitative descriptors of population density (Table 2).

Maximum characteristic dimension of the UAS		1 m/ aprox. 3 ft	3 m/ aprox. 10 ft	8 m/ aprox. 25 ft	20 m/ aprox. 67 ft	40 m/ aprox. 130 ft
Maxium population density iGRC (persons/ km²)	Controlled area on the ground	1	1	2	3	3
	<5	2	3	4	5	6
	<50	3	4	5	6	7
	<500	4	5	6	7	8
	<5.000	5	6	7	8	9
	<50.000	6	7	8	9	10
	<50.000	7	8	No forma part del SORA		

- A UAS weighing less than or equal to 250 g and with a maximum speed of less than or equal to 25 m/s is considered to have an iGRC of 1 regardless of population density.
- A UAS that is not expected to penetrate a standard dwelling will obtain a reduction of -1 in the GRC at stage 3 of mitigation M1(A) (sheltering), provided that it does not fly over large gatherings of people. See Annex B of SORA 2.5 for further details.

Table 1. Intrinsic Ground Risk Class (iGRC) of UAS

Population (persons/km ²)	Qualitative descriptors	Description of the area
Controlled ground area	Controlled ground / extremely remote	Controlled areas where unauthorised persons cannot access. Areas with difficult access (mountains, remote deserts, etc.), large bodies of water far from maritime traffic, where it is reasonable to expect no people to be present.
< 5	Remote	Areas where people may be present, such as forests, deserts, large farm plots, etc. Areas where approximately one small building per km ² may be found. Areas of maritime traffic where it is reasonable not to expect people.
< 50	Sparsely populated	Small farm areas. Residential areas with large plots (4 acres or 16,000 m ²)
< 500	Lightly populated / low-density residential	Areas consisting of housing and small businesses with large plots (1 acre or 4,000 m ²)
< 5.000	Suburban/ low metropolitan density	Areas of single-family homes on small plots, apartment complexes, commercial premises, etc. May include several storeys, but generally should have fewer than 3 or 4 floors.
< 50.000	High metropolitan density	Areas predominantly composed of buildings. The centre of most cities. Areas with high-rise density.
> 50.000	Gatherings of people	The densest areas of large cities. Large gatherings of people such as professional sporting events, large concerts, etc.

Table 2. Qualitative descriptors for estimating population density

Once the intrinsic GRC has been obtained, the operator may apply strategic mitigations to reduce the final risk level (Table 3). In the case of transporting samples and healthcare pharmaceuticals, the most relevant are:

- **M1(B) Strategic mitigation based on operational restrictions:** overflying

locations at off-peak times to ensure that the actual population density during the operation is lower than the theoretical one

- **M2 (Reduction of impact effects):** use of certified parachutes to reduce impact energy in the event of a critical failure

Ground risk mitigations	Low of robustness		
	Low	Moderate	High
M1(A) - Strategic mitigations – Shelter	-1	-2	N/A
M1(B) - Strategic mitigations – Operational restrictions	N/A	-1	-2
M1(C) - Tactical Mitigations – Ground Observation	-1	N/A	N/A
M2 – Reduction of UAS impact dynamics effects	N/A	-1	-2

Table 3. Mitigations for determining final GRC

- **Air Risk (ARC, Air Risk Class):** it assesses the probability of conflict and collision with other aircraft using the airspace. It is defined according to altitude, the type of airspace (controlled / uncontrolled), proximity to aerodromes and the type of environment (urban / rural). In BVLOS medical transport operations, this is often the most critical aspect.

*** Initial ARC:** it is determined according to the airspace in which the operation takes place (controlled airspace, airport environment, etc.). ARC levels are classified from a to d based on the probability that the drone encounters another aircraft during the operation. a corresponds to negligible probability and d to high probability (Figure 1).

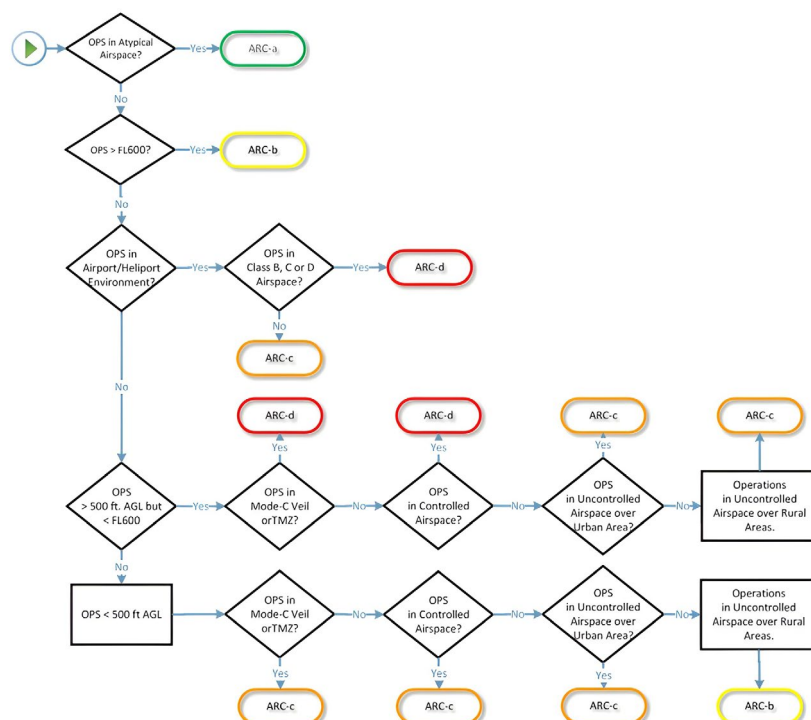


Figure 1. Decision tree for determining initial air risk

*** Strategic and tactical mitigations:**

to reduce air risk, it is necessary to implement solutions such as segregated routes (strategic) or Detect and Avoid systems (tactical) that allow the drone to detect other aircraft and avoid them autonomously.

The combination of final ground risk, residual air risk and the applied mitigation measures results in the **SAIL (Specific Assurance and Integrity Level)** which defines the level of operational risk (Table 4). The SAIL is an indicator ranging from **I (low risk)** to **VI (very high risk)** and

establishes the level of technical, procedural and training requirements needed to obtain flight authorization.

- **Low SAIL (I-II):** low-risk operations with basic requirements.
- **Medium SAIL (III-IV):** operations with greater complexity, requiring robust procedures and additional evidence.
- **High SAIL (V-VI):** operations close to the certified category, with high technical and safety requirements.

Final GRC	Residual ARC			
	A	B	C	D
≤ 2	I	II	IV	VI
3	II	II	IV	VI
4	III	III	IV	VI
5	IV	IV	IV	VI
6	V	V	V	VI
7	VI	VI	VI	VI
> 7	Operational category C (certified)			

Table 4. SAIL determination

As established in SORA 2.5, the determination of the SAIL is not an independent process, but the result of combining ground risk (final GRC) with air risk (residual ARC). The interaction between these two parameters is articulated in a decision table (Table 7 of the official guide), which allows assigning the SAIL level associated with the proposed operation. In this report, this information has been incorporated into Table 4, which clearly shows how the SAIL is determined from the final GRC and the residual ARC.

Each SAIL level corresponds to a set of Operational Safety Objectives (OSO), which are the requirements that the operator must comply

with and demonstrate to the authority (Table 5).

These are divided into:

- **Technical:** drone integrity, software design, containment systems (geofencing)
- **Operational:** operations manuals, emergency procedures, checklists
- **Human:** theoretical and practical training for remote pilots and maintenance personnel, adapted to the complexity of medical flights

OSO ID	Operational Safety Objective	SAIL						Dependencies (Critical references according to Annex E of SORA 2.5)		
		I	II	III	IV	V	IV	Operator	Training org.	Designer
OSO#01	Ensure that the operator is competent and/or proven	NR	L	M	H	H	H	X		
OSO#02	UAS manufactured by a competent and/or proven	NR	NR	L	M	H	H			X
OSO#03	UAS maintained by a competent and/or proven entity	L	L	M	M	H	H	Crit. 1 Crit. 2		Crit. 1
OSO#04	UAS components essential for safe operations designed to an airworthiness design standard (ADS)	NR	NR	NR	L	M	H			X
OSO#05	UAS designed considering system safety and reliability	NR	NR ^c	L	M	H	H			X
OSO#06	C3 link characteristics are adequate for the operation	NR	L	L	M	H	H	X		X
OSO#07	C3 link characteristics are adequate for the operation	NR	L	L	M	H	H	Crit. 1 Crit. 2		Crit. 1
OSO#08	Operational procedures defined, validated and followed	L	M	H	H	H	H	X		Crit. 1
OSO#09	Trained and current remote crew	L	L	M	M	H	H	X	X	
OSO#13	External services supporting UAS operations are adequate for the operation	L	L	M	H	H	H	X		
OSO#16	Multi-crew coordination	L	L	M	M	H	H	Crit. 1 Crit. 2	Crit. 2	
OSO#17	Remote crew fit to operate	L	L	M	M	H	H	X		
OSO#18	Automatic protection of the flight environment against human error	NR	NR	L	M	H	H			X
OSO#19	Safe recovery from human errors	NR	NR	L	M	M	H			X
OSO#20	A human factors assessment has been conducted and the HMI has been considered adequate for the mission	NR	L	L	M	M	H	X		X
OSO#23	Environmental conditions for safe operations defined, measurable and respected	L	L	M	M	M	H	X		X
OSO#24	UAS designed and qualified for adverse environmental conditions	NR	NR	M	H	H	H			X
According to the guidelines, NR = Not required and indicates that it is not necessary to demonstrate compliance to the competent authority; however, the applicant is encouraged to consider the operational safety objective with a low level of integrity. L = Low; indicates that the objective is recommended with low robustness. M = Medium; indicates that the objective is recommended with medium robustness. H = High; indicates that the objective is recommended with high robustness.										

Table 5. Recommended Operational Safety Objectives (OSO)

2.2.2 Application of the SORA methodology to the transport of samples and pharmaceuticals with drones in Catalonia

The following table shows a hypothetical example of the application of the SORA 2.5 methodology to the transport of samples and pharmaceuticals with drones.

As indicated in the Scope chapter, the methodology will be applied in the case of an unmanned aircraft of less than 25 kg MTOM, with characteristic dimensions of up to 3 metres, maximum speed below 35 m/s and redundancy of communication systems, operating in BVLOS within the specific category (Table 6):

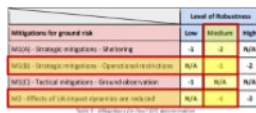
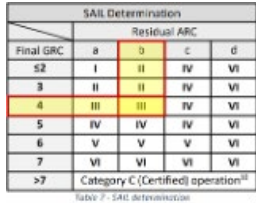
SORA component	Scenario description	Methodology	Result
1. Concept of Operations (ConOps)	Transport of blood/biological samples. BVLOS at low altitude (below 120 m) between medical centre A and medical centre B.		Environment: Suburban - population density of up to 5,000 inhabitants/km ²
2. Ground Risk (GRC)	Characteristic dimension of the drone: up to 3 m wingspan Environment: Suburban - population density of up to 5,000 inhabitants/km ²		Intrinsic GRC: 6
GRC Mitigation (M1(B))	Overflying industrial or commercial areas during weekends or non-working hours.		GRC 6 - 1 = 5
GRC Mitigation (M2)	Certified parachute system: reduction of ground risk (GRR) of approximately 90% under SORA guidelines (medium integrity)		Final GRC 5 - 1 = 4
3. Air risk (ARC)	Type of airspace: flight below 500 ft AGL in uncontrolled airspace over an urban area		Initial ARC: c
ARC Mitigation	Tactical mitigation (BVLOS): integration of a robust DAA (Detect and Avoid) system and ADS-B transponder to detect manned aircraft		Final ARC c -> b (Reduction due to demonstrated collision avoidance capability)
4. SAIL determination	Calculation: Final GRC x Final ARC		4 x b = SAIL III

Table 6. Example of healthcare logistics operational planning

In the operational use case considered, with a final GRC of 4 points (5,000 inhabitants/km²) and a final air risk of ARC-b, the resulting risk

level is SAIL III, which will be the operational limit considered.

3.

Methodology

3.1 Indicators

To analyse the feasibility of deploying drone flights in the healthcare sector, this report is based on five dimensions: **1) Healthcare, 2) Territory, 3) Operational risk, 4) Logistics and 5) Operational coordination**. Each of the dimensions incorporates a set of specific indicators. The selection and definition of these indicators were carried out in a participatory online session with representatives of the participating entities, which made it possible to prioritise the most relevant indicators and agree on the evaluation criteria in order to achieve a multidisciplinary view aligned with the real needs of the healthcare system.

1. Healthcare

This dimension aims to analyse the structure and needs of the Catalan healthcare system by identifying the main healthcare nodes and the potential flows for transporting biological samples and healthcare materials.

1.1 Territorial healthcare structure

This subsection focuses on the identification and distribution of the main healthcare resources of the public health system (SISCAT), as a basis for understanding territorial coverage and possible connectivity needs. The main indicators in this subsection are:

- Number and distribution of hospitals, primary care centres (CAP) and local clinics (CL)
- Density and distribution of healthcare centres
- Location of SEM bases (heliports)

1.2 Healthcare and sample flows

This subsection analyses how referral and transport flows are organised within the healthcare network, with the aim of understanding which points generate a higher volume of samples or materials to be transported. The main indicators used in this subsection are:

- Reference centres and their relationship with associated centres, to describe hierarchy and transport circuits
- Volume of samples transported
- Location of intermediate centrifugation centres

2. Territory

This dimension analyses the physical and infrastructural characteristics of the territory that may influence the implementation and operation of drone services.

Its objective is to identify the conditions that may favour or limit the deployment of flights, both from a safety perspective and from a technical and logistical feasibility standpoint.

Various territorial aspects that directly affect route planning and the location of take-off and landing points (and future UAS infrastructure and vertiports) have been considered. The main indicators are:

- Population density: to identify areas where greater safety measures or flight restrictions are required
- Orography and terrain characteristics: to detect natural obstacles and conditions that may affect flight trajectory or stability
- Protected natural areas: including protected natural areas and those forming part of the Natura 2000 Network (ZEPA and LIC/ZEC areas)
- Land infrastructure: including both artificial constructions (e.g. roads) and green infrastructure (rivers, natural corridors), which may act as safe corridors for drone air traffic
- Port, airport and aeronautical infrastructure: including the location of commercial and sports ports of the Generalitat de Catalunya as well as all airport infrastructure (heliports, aerodromes and airports)

3. Operational risk

This dimension assesses the level of risk and the feasibility of drone flight operations, both at territorial and hospital level. The objective is to identify those areas and centres that allow operations to remain within acceptable safety margins (SAIL III), in accordance with the criteria established by the SORA 2.5 methodology.

For this analysis, several territorial and aerial elements have been considered, such as population density maps (GRC) at Catalonia level, the structure of the airspace and the presence of controlled airspace (CTR), critical

facilities and infrastructure, and the physical and infrastructural characteristics of hospitals. Within this dimension, two main indicators have been defined:

- Ground risk, which assesses population and territorial exposure associated with a flight operation, calculated based on the SORA methodology and expressed through the ground risk level (GRC).
- Hospital feasibility, which integrates the analysis of air risk (ARC), calculated based on their location in relation to CTR zones, their surroundings (nearby infrastructure, exclusion zones of nuclear power plants and surrounding buildings) and the characteristics of potential take-off and landing areas within the centres themselves.

These two indicators constitute the core of the operational risk analysis. GRC and ARC values that result in operations not exceeding SAIL III have been set as operational limits. To enable quick visualisation of the areas where route deployment is currently more feasible, a population density layer divided into 1 km² sectors has been created. Additionally, to identify areas where it would be more difficult to deploy stable routes, a layer has been created showing 1 km² sectors where population density exceeds 5,000 inhabitants/km², a threshold at which ground risk would cause any operation with a drone of the characteristics defined in the Scope to exceed SAIL III and therefore fall outside the proposed operational scenario.

4. Logistics

This dimension analyses the logistical feasibility of using drones compared to traditional road transport, taking into account efficiency, cost and environmental sustainability criteria.

Its objective is to assess in which contexts drone transport may represent an operational or environmental advantage over conventional systems.

- Average distance and transport time: comparison between road routes and drone routes to assess potential gains in speed and accessibility.

- Environmental impact: estimation of CO₂ emissions and energy consumption of road transport compared to drone transport.
- Cold chain maintenance: ability to preserve temperature and ensure product quality during transport, particularly relevant for healthcare or pharmaceutical shipments.

5. Operational coordination

According to Article 2 of Commission Implementing Regulation (EU) 2019/947 on the rules and procedures for the operation of unmanned aircraft, a UAS geographical zone is a portion of airspace established by the competent authority that facilitates, restricts or excludes UAS operations in order to manage risks related to safety, security, privacy, personal data protection or the environment.

In these environments, in order to carry out operations safely and efficiently, communication, declaration, permission requests or operational coordination initiated by the UAS operator and addressed to the different managing bodies and competent authorities of the affected territory are required.

For this reason, this section analyses areas with territorial and institutional elements that may influence the planning and safe execution of drone operations. This task involves considering several key factors before and during missions. Considering these elements makes it possible to better plan routes, identify potential restrictions and ensure optimal integration with existing security, emergency and surveillance operations, as well as the safe integration of manned and unmanned aircraft. The main indicators in this operational coordination section are:

- Protected natural areas
- Emergency helicopter bases
- Location of airports, heliports and future heliports of the H24 network
- Location of commercial and sports ports
- Security and emergency networks (Mossos d'Esquadra, local police, Guardia Civil and security and emergency forces)
- Linear infrastructure network (roads)

At this point, it is important to clarify that the operational safety areas surrounding heliports of the security and emergency network have not been represented on the maps, as it is assumed that the operations proposed in this study will have the necessary administrative and bureaucratic arrangements in place to ensure coordination between emergency medical system infrastructure and the UAS operators executing the use case. This approach aims to minimise the visual burden of maps and restricted or limited areas, while also conveying that, despite limitations, it is possible to transport samples and pharmaceuticals by drone in compliance with the current legal framework.

On the other hand, the maps do not include graphical representation of:

- Protection areas around other aerodromes and airfields.
- Restricted UAS geographical zones according to the AIP, such as Aiguestortes i Estany de Sant Maurici National Park (LER112) and the Ebro Delta Natural Park (LER30).
- UAS geographical zones restricted for photographic flights.
- Areas where aeronautical sports activities may take place, such as skydiving.
- Temporary Segregated Airspace (TSA), which is a volume of airspace of defined dimensions, temporarily established for the exclusive use of specific aeronautical activities.

In all these areas, it is assumed that stakeholders will have the necessary communication and administrative coordination mechanisms in place to ensure that drone

operations can be carried out in accordance with the current legal framework.

3.2 Zone analysis methodology

In accordance with the indicators defined in the previous section and the operational scenario set out in this report, the following methodology has been defined to select the key areas where the deployment of drone routes will be prioritised.

In an initial phase, the healthcare coverage of centres and SEM emergency heliports was analysed to assess the territorial distribution of healthcare services. This analysis made it possible to identify areas where hospital and primary care are interconnected and, subsequently, to define logistical routes consistent with the healthcare model and of high healthcare relevance.

Next, the territory and infrastructure of Catalonia will be analysed to identify areas where drone air transport may represent an advantage over road transport. For the prioritisation of parts of the territory, the following criteria will be applied:

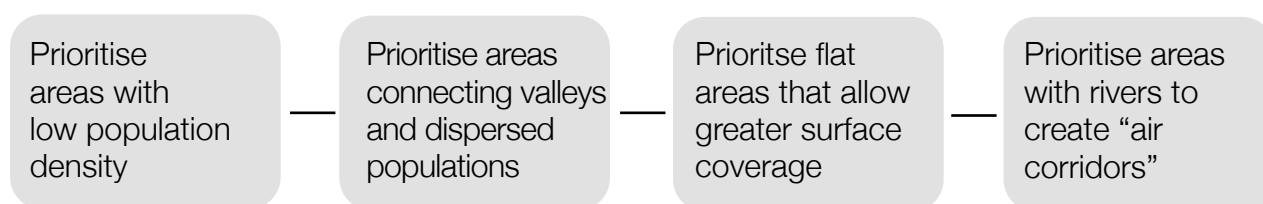


Figure 2. Criteria for prioritizing areas

Additionally, a classification of the 69 hospitals and public health centres of the SISCAT will be carried out, selecting as possible viable

candidates those that meet the following established operational criteria:

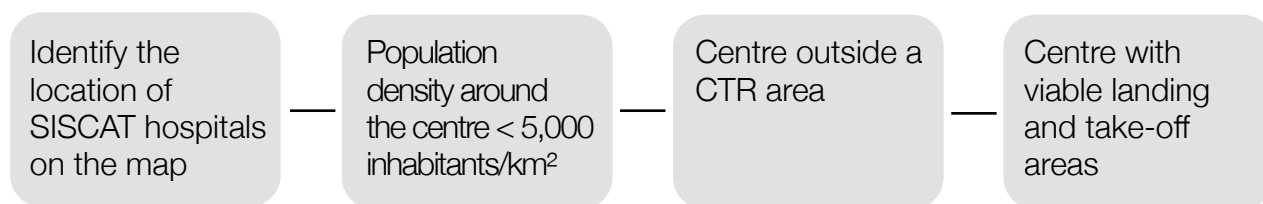


Figure 3. Criteria for selecting viable centres

In the areas and regions that meet the above criteria, the analysis will be expanded to include a study of logistics, the number of centres and the healthcare activity volume of the area.

The analysis has been structured in several successive phases. It began with territorial and operational feasibility indicators, which make it possible to identify the most suitable candidate areas for the deployment of drone flights in the healthcare sector.

Based on these candidate areas, two additional groups of indicators have been analysed:

- **Logistical indicators**, which make it possible to assess aspects of the potential efficiency of drone transport compared to road transport, such as time, distance, energy consumption or CO₂ emissions.
- **Healthcare indicators**, focused on the distribution and activity volume of healthcare centres, the number of samples handled and the presence of intermediate processing points.

Finally, complementary indicators for operational coordination within the candidate areas will be presented, including the location of ports, airports, heliports, natural parks and security networks (Mossos d'Esquadra, local police, Guardia Civil, etc.). These elements provide a comprehensive view of the territorial and operational context required to plan and execute flight routes safely and efficiently.

3.3 Methodology for geographical analysis

In order to analyse geographical data and the location of the different infrastructures in the territory, the team from the Personalised Digital Care Area of the TIC Salut Social Foundation has developed an analysis and visualisation tool in the form of a dynamic and interactive map that allows users to select which layers to display. This dynamic functionality makes it possible to compare different variables or indicators simultaneously and visually in order to identify characteristics across the entire territory.

There are different base maps. The most appropriate one can be used depending on the information to be displayed or highlighted:

- Neutral map
- Basic map
- Satellite map (with labels)
- Satellite map (without labels)
- Topographic map
- Administrative map

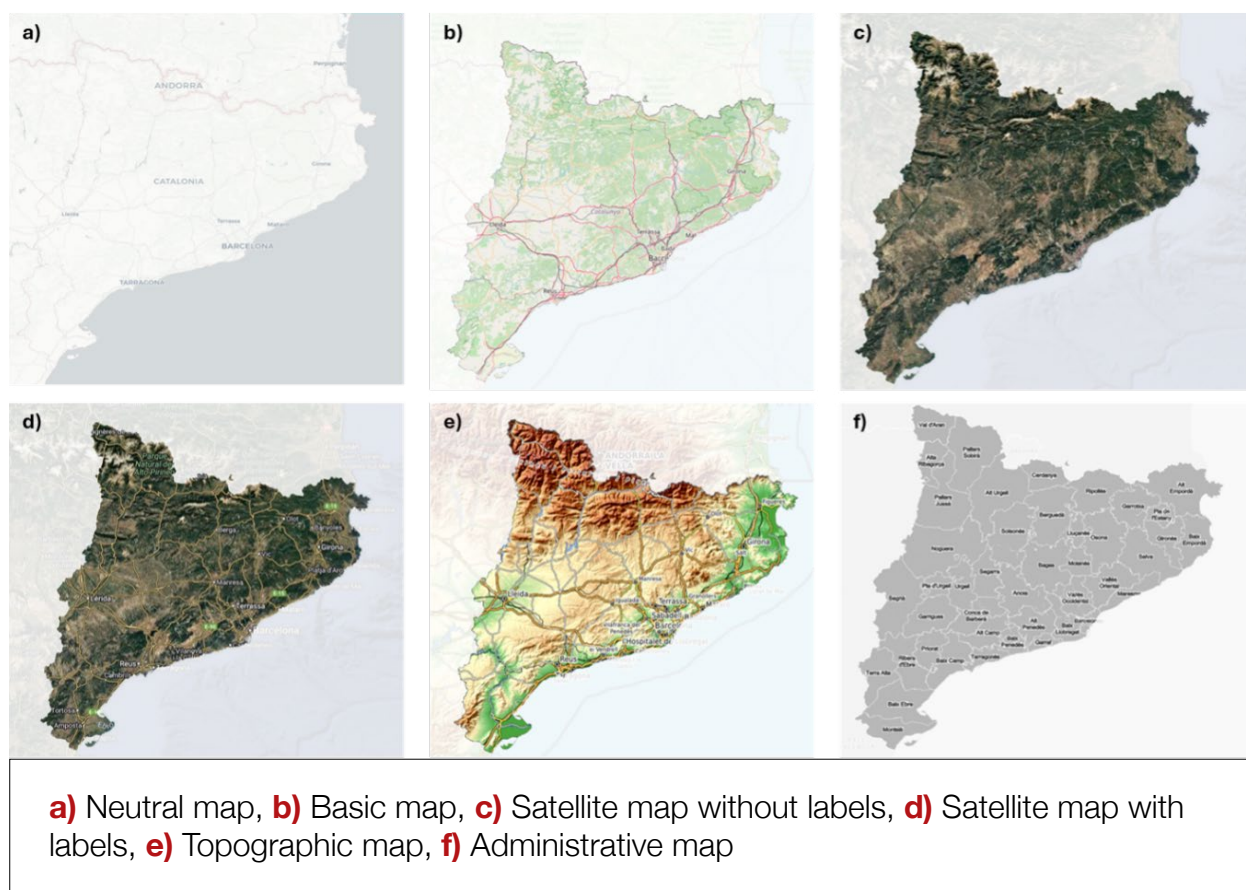


Figure 4. Different base maps included in the interactive map

On these base maps, different layers can be added, which can be combined unlimitedly and

can be classified according to Table 7.

Grouping of layers	Layers	Example of grouping
Administrative geographical	* Catalonia * Health regions (RS) * Health sectors (HS) * Basic health areas (ABS) * Healthcare management areas (AGA) * County boundaries * Municipal boundaries * Population by county	

Table 7. Classification and examples of layers included in the interactive map

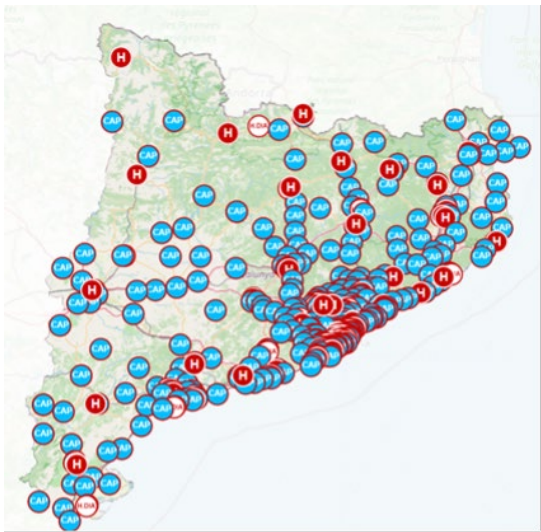
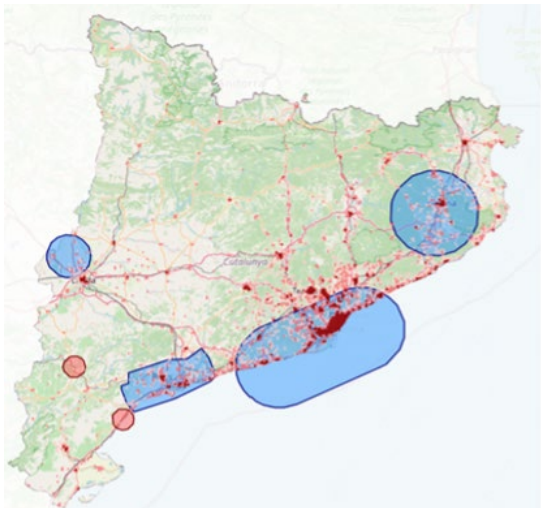
Grouping of layers	Layers	Example of grouping
Healthcare	* Hospitals * Primary care centres (CAP) * Primary care emergency centres (CUAP) * Day hospitals for socio-health care * Local clinics (CL) * Layer with viable hospitals* * Layer with non-viable hospitals*	
Territory	* Protected natural areas * Natura 2000 Network * Internal basins of Catalonia * Rivers of Catalonia * Slopes > 20%	
Drone risk analysis	* Airspace zones with restrictions * Ground risk distribution* * Sectors with population density > 5,000 inhabitants/km² *Population density in 1 km² sectors	

Table 7. Classification and examples of layers included in the interactive map

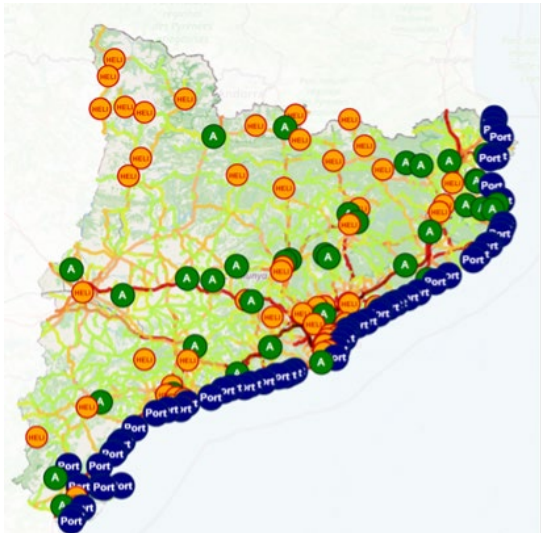
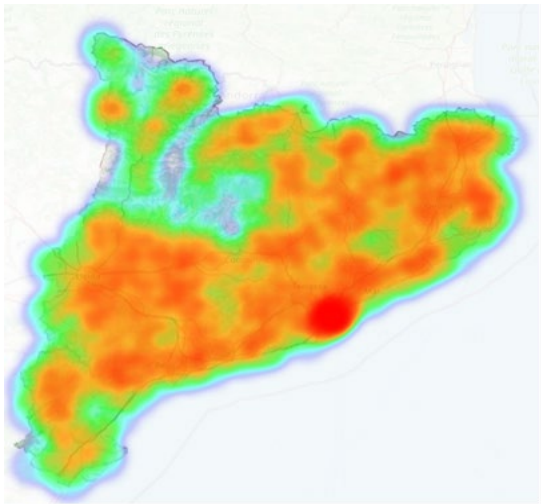
Grouping of layers	Layers	Example of grouping
Civil security networks	* Comissaries de policia local * C * Local police stations * Mossos d'Esquadra police stations * National Police stations * Guardia Civil stations	
Infrastructures	* SEM Heliports * Other heliports * Aerodromes and airports * Ports of the Generalitat de Catalunya * Road network * Traffic intensity on roads	
Densities	* Density of CAPs * Density of CLs * Density of all health centres * Population density	

Table 7. Classification and examples of layers included in the interactive map

All the layers mentioned have been developed using data from various sources, both public and internal, or generated specifically for this project through collaborations with specialised entities.

The list of data sources used to develop the map layers can be found in Annex II.

Finally, certain specific functional features have been added, specifically connectors that allow different actions on the map, such as zooming, activating the user's location or defining operation areas by measuring distances in a straight line or by delimiting areas (polygons, squares, circles or points), defined based on a maximum operating distance from different points. These utilities can be used in real route simulation cases to determine distances between points of interest, select the types of drones that can be used in each case, define approximate distances between the various points along the routes and display on the map the surface area that different types of drones can cover. The zoom functionality allows users to take advantage of the responsive functions of the base maps to view relevant geographical or administrative details shown by these layers and consider them when calculating a route layout.

To facilitate the visualisation of areas of interest on the maps, a white filter has been applied to blur or soften areas that are not intended to be highlighted. Several filters have been created, each designed to meet the specific needs of this report. Therefore, an unlimited number of filters can be created following the methodology used to create the existing filters.

The map has been developed in Python 3.13 using the Pandas and Folium 0.20.0 libraries. The latter library allows the generation of an HTML file with the map so that it is dynamic, responsive and interactive. Some functionalities, such as the presence of the TIC Salut Social Foundation logo or the filter window, have been programmed directly in Javascript due to limitations of the Folium library.

In the ADP area, the map is routinely used to identify and verify the feasibility of drone use cases in the healthcare sector, measure distances between centres and plan routes in future projects.

4.

Results

This section presents the results of the analysis of the healthcare system, the territory and the operational risk of SISCAT hospitals, with the aim of identifying population distribution, orography and operational constraints in Catalonia in order to determine which centres and areas offer the greatest operational potential.

4.1 Healthcare: territorial healthcare structure (SISCAT)

The distribution of healthcare centres in Catalonia shows differentiated territorial patterns depending on the type of centre and population density.

Hospitals (Figure 5a) are distributed fairly evenly except in the Pre-Pyrenees and the western Pyrenees, where rugged terrain limits healthcare coverage, and in the Barcelona metropolitan area and surrounding towns, where there is a high density, including the main referral centres. In areas further away from hospitals, there are primary healthcare centres that help ensure healthcare coverage, even if on a smaller scale.

Analysing primary care centres (CAP), the highest concentration is found in the Barcelona area and surroundings, the Vallès regions, Girona, Manresa, the Garraf coast and the Camp de Tarragona. The remaining CAP are distributed fairly evenly across the eastern half of Catalonia, following the south-north axis defined by the C-16 (Figure 5b).

In the south-western part of Catalonia (regions of Ribera d'Ebre, Priorat, Conca de Barberà and Les Garrigues) and in the regions of Lleida, Alt Pirineu and Aran, CAP are only located in the main population centres.

Regarding the distribution of local clinics (CL), the main concentration is found in five areas: Empordà, Plana d'Urgell, Alt Penedès, northern Tarragona and Priorat. There is also a concentration of centres in the Vic plain (Figure 5c).

Overall, these data show that, despite the concentration of hospitals in large urban centres, primary care contributes to ensuring more homogeneous territorial coverage, especially in peripheral areas.

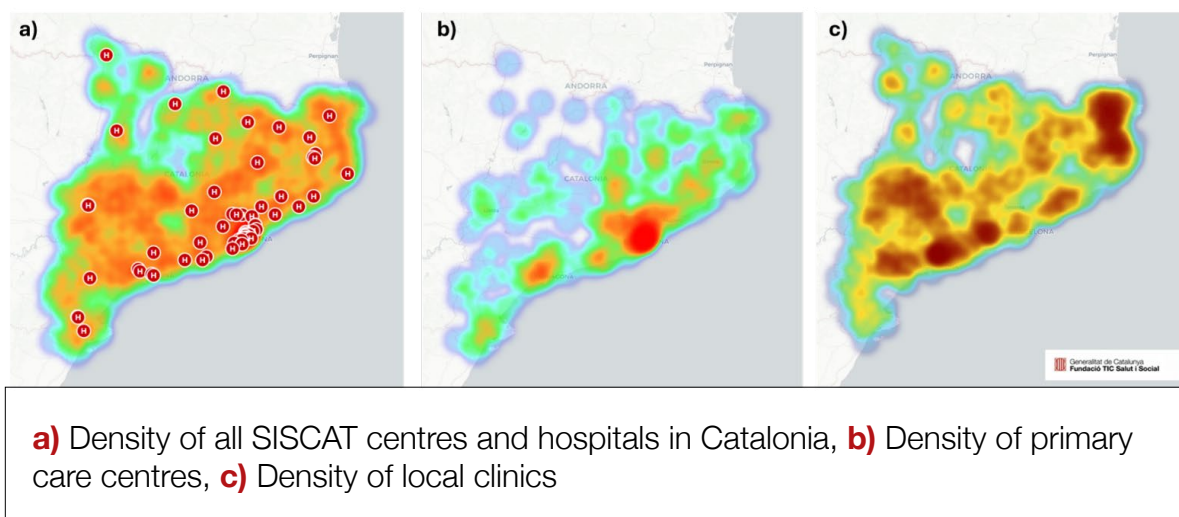


Figure 5. Density and distribution of health centres in Catalonia

On the other hand, the distribution of SEM bases is mainly concentrated in major referral hospitals in Barcelona, Mataró, Reus, Tarragona and Girona, as well as in some regional hospitals such as those in Móra d'Ebre, Tortosa or Tremp. There are also bases located outside

hospitals, as in the case of the Vilaller base. This configuration shows that the territory has good SEM operational coverage, especially in the Terres de l'Ebre, the Pallars and Ribagorça areas, the Camp de Tarragona and the Girona area (Figure 6).

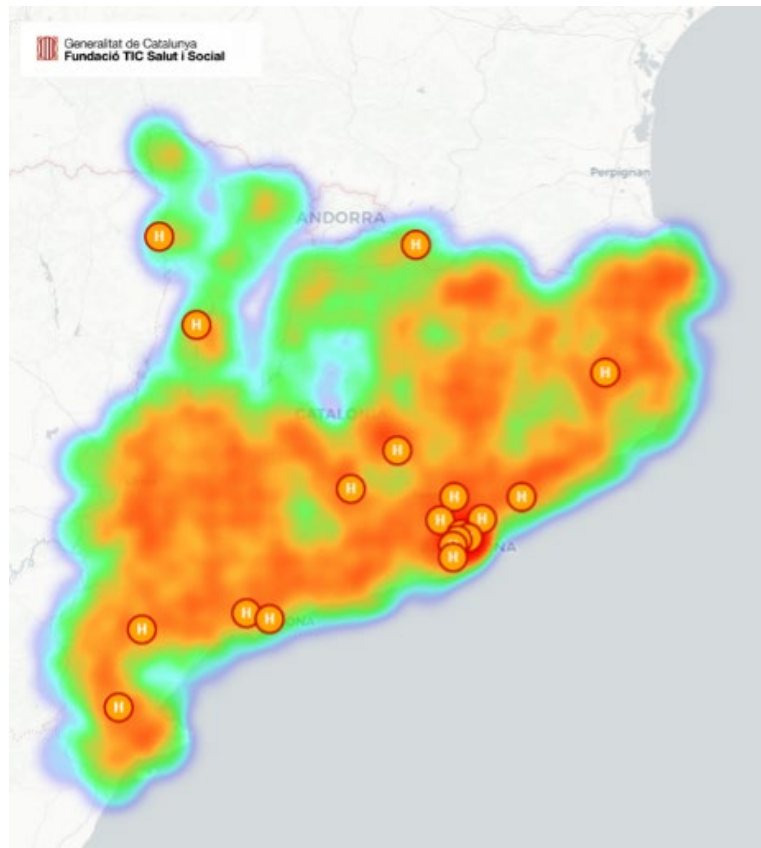


Figure 6. Distribution of SEM bases

The map in Figure 4 shows the current network of SEM heliports. This network is expected to grow in the coming years thanks to Government Agreement GOV/126/2025, of 13 May, which approves the H24 emergency heliport strategy of the Government of Catalonia. The main objective of this strategy is to establish and develop a network of emergency heliports capable of operating 24 hours a day (H24) throughout Catalonia in order to strengthen the Government's aerial operational capacity. The implementation of this network aims to significantly improve accessibility and response times of emergency services, especially healthcare and civil protection services, ensuring maximum efficiency in the transfer and care of patients. These new territorial heliports will be established in the following areas:

Alta Ribagorça, Pallars Sobirà, Pallars Jussà, Alt Urgell, Cerdanya, Ripollès, Garrotxa, Alt Empordà, Selva, Berguedà, Solsonès, Moianès, Noguera, Segarra, Les Garrigues, Conca de Barberà, Anoia, Baix Camp, Ribera d'Ebre, Terra Alta, Baix Ebre and Montsià.

4.2. Territory

The results are shown in the interactive map, where different territorial indicators can be visualised to analyse the areas and regions where operations are more viable and where air transport offers an advantage over road transport. This representation facilitates the identification of optimal flight areas while ensuring the safety and efficiency of operations.

4.2.1 Population density

The population density map of Catalonia shows a high population density and, therefore, a concentration of urban areas in the Barcelona metropolitan area, Empordà, the Tarragona-Reus areas and Baix Penedès. These areas have lower priority because routes would involve greater operational risk.

In the Plana d'Urgell and Central Catalonia, a fairly uniform population distribution can be observed. In this area, there is a notable population concentration in the Osona region. Finally, low population density can be observed

in the Pre-Pyrenees and the western Pyrenees. In these areas, the population is concentrated in the Pallars, Alt Urgell and Vall d'Aran regions (Figure 7).

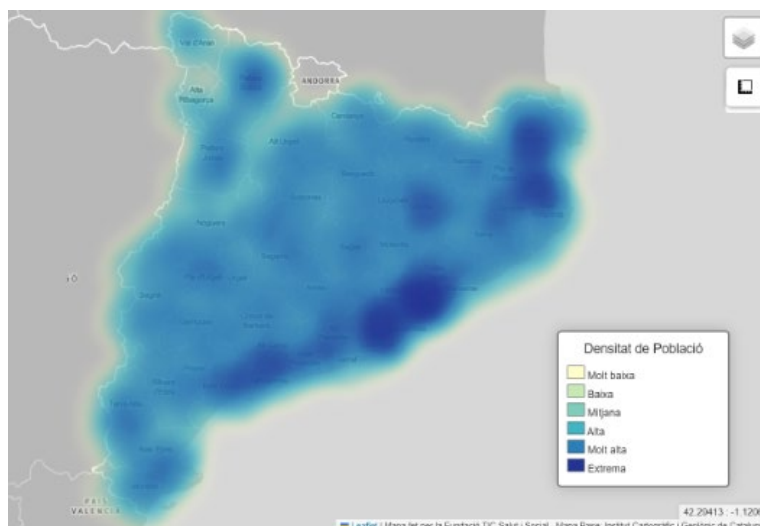


Figure 7. Population density map in Catalonia

4.2.2 Orography and terrain characteristics

The variety of landscapes and activities in Catalonia, ranging from high-density urban areas to rural or natural areas, determines the suitability of each territory for drone use. The Catalan territory is segmented by the main mountain systems that cross it: the Pyrenees, the Pre-Pyrenees, the Pre-coastal range and the Coastal range.

First, it is useful to focus the analysis on the latter two mountain systems. The main urban centres of Catalonia are located along the coast and in the area between the Coastal and Pre-coastal ranges.

In the southernmost coastal area, a plain opens around the towns of Tortosa, Amposta and the Ebro Delta. This is a flat area with little rugged relief and therefore of operational interest.

Beyond the Pre-coastal range lie the main plains of Catalonia. The western plain, the central plateaus (Manresa area) and the Vic plain. These are areas with gentler relief and therefore allow for operations that can generate a higher volume of routes. To the east of the Vic plain, separated by the Transversal range, lie the Empordà plain

to the north and the Girona area to the south. To the north of the plains begins the entire area covered by the Pre-Pyrenees, with more rugged terrain where the use of air transport offers an advantage, as it allows elevation differences to be overcome more smoothly and avoids winding roads.

The eastern Pre-Pyrenees, east of the Segre valley and above the central plateaus and the Vic plain, include the regions of Solsonès, Berguedà, Ripollès and Garrotxa, extending up to the highest slopes of the eastern Pyrenees.

The western side of the Pre-Pyrenees includes Pallars, Alt Urgell and Alta Ribagorça, the regions located between the Montsec range and the axial Pyrenees. Finally, the two northernmost areas of Catalonia are the Cerdanya valley, located southeast of Andorra and extending into France, and the Val d'Aran, the only territory north of the axial Pyrenees, which therefore has the most difficult access in Catalonia.

In summary, the analysis of orography and population density allows two priority areas to be identified: first, the western plain (Lleida), the Vic plain and the Terres de l'Ebre (from Tortosa to the Ebro Delta), which are flat areas where a high volume of routes can be defined;

and second, the areas crossed by the Pre-Pyrenean range (from Alta Ribagorça in the west to Garrotxa in the east), where air transport would enable the interconnection of valleys and dispersed mountain settlements (Figure 8).

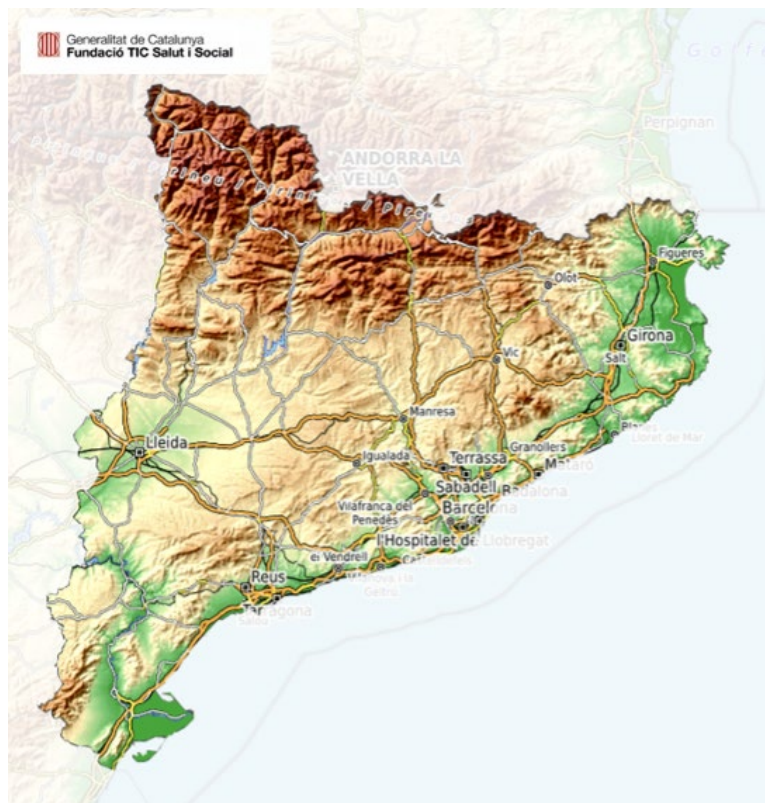


Figure 8. Orography of Catalonia

4.2.3 Infrastructures

To determine the operational feasibility of drone routes, a set of infrastructures in Catalonia has been analyzed: fluvial infrastructure (rivers and streams), land infrastructure (roads), and port, airport and aeronautical infrastructure (heliports, aerodromes and ports). In all cases, the priority is to avoid areas with the presence of people or vehicles in order to favor safe corridors with low interaction with third parties..

i) Fluvial infrastructure

Rivers and canals in Catalonia generally have very low or no vessel traffic, except for the final stretch of the Ebro and areas with occasional water-based activities. This makes fluvial resources good operational corridors, as they allow flights over areas without regular human circulation (Figure 9a).

The fluvial network of Catalonia is divided into:

- **Internal basins:** they cover the Llobregat–Cardener area (north–south axis), the Ter system and tributaries crossing Osona, Girona and Baix Empordà.
- **External basins:** Noguera Ribagorçana, Noguera Pallaresa and Segre, which flow into the Ebro; and the Ebro River itself in the south of the country.

ii) Land infrastructures

The analysis of traffic distribution in Catalonia makes it possible to identify the main traffic concentration points and, therefore, the areas where roads with high AADT would complicate operations.

The key indicator for assessing safe routes is the average annual daily traffic (AADT): the lower the AADT, the lower the probability of flying over vehicles and, therefore, people (Figure 9b).

The main high-traffic points that should therefore be avoided are:

- Metropolitan area of Barcelona and main access routes

- AP-7, which runs along the prelittoral from north to south and concentrates the highest AADT values
- Nodes of Manresa, Vic and Girona-Figueres
- Maresme Road (Barcelona-Blanes) and A-2 between Barcelona and Lleida
- AP-2 and its connections with El Vendrell and Tarragonès

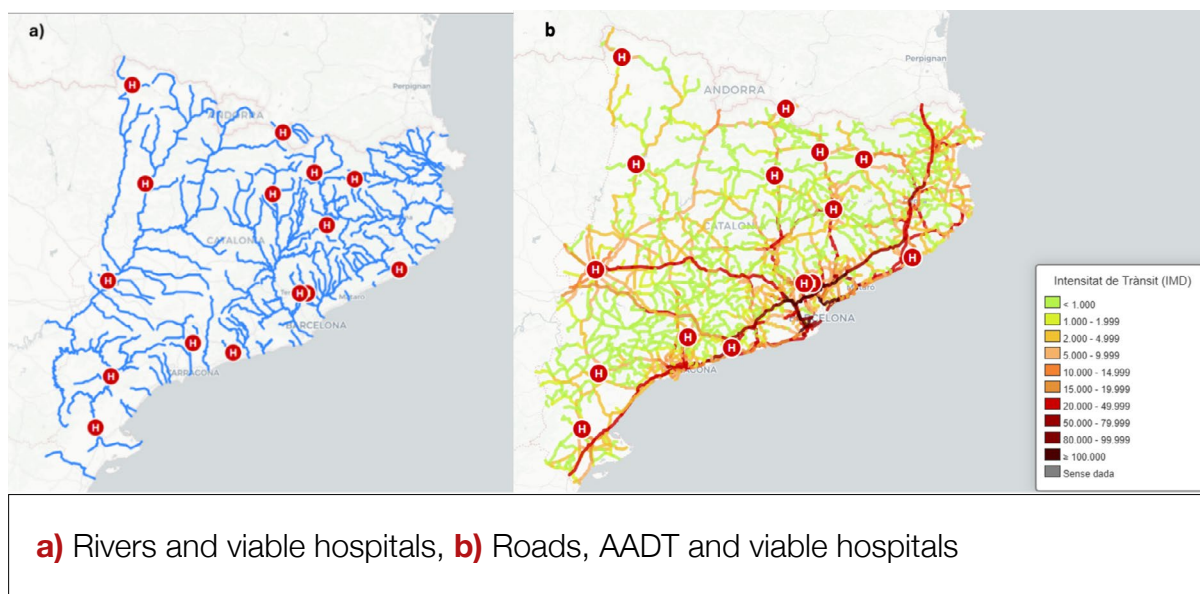


Figure 9. Map of fluvial and land infrastructure in Catalonia

ii) Port, airport and aeronautical infrastructures

This network includes commercial and sports ports, aerodromes and airports, SEM heliports and temporary heliports (firefighters, ski resorts). Ports are continuously distributed along the entire coastline and the final stretch of the Ebro. This distribution makes it possible to plan logistics operations combining land and water routes. It also enables interconnection between centers and ports.

Airports and aerodromes provide controlled air traffic zones (except installations under strict CTR) and reduce the risk of conflict with uncontrolled aircraft. They are distributed throughout the territory except in the Alt Pirineu, with notable presence only in La Seu d'Urgell and Cerdanya.

Heliports are highly concentrated in the Barcelona Metropolitan Area, in the Reus–

Tarragona area, in Girona and in the main urban centers along the Ebro River (Móra d'Ebre, Tortosa, Amposta). In the rest of the territory, especially in the Pre-Pyrenees and the Pyrenees, temporary heliports linked to ski resorts stand out. There are also relevant points in Lleida and on the Costa Brava.

*CTR zones are represented in blue

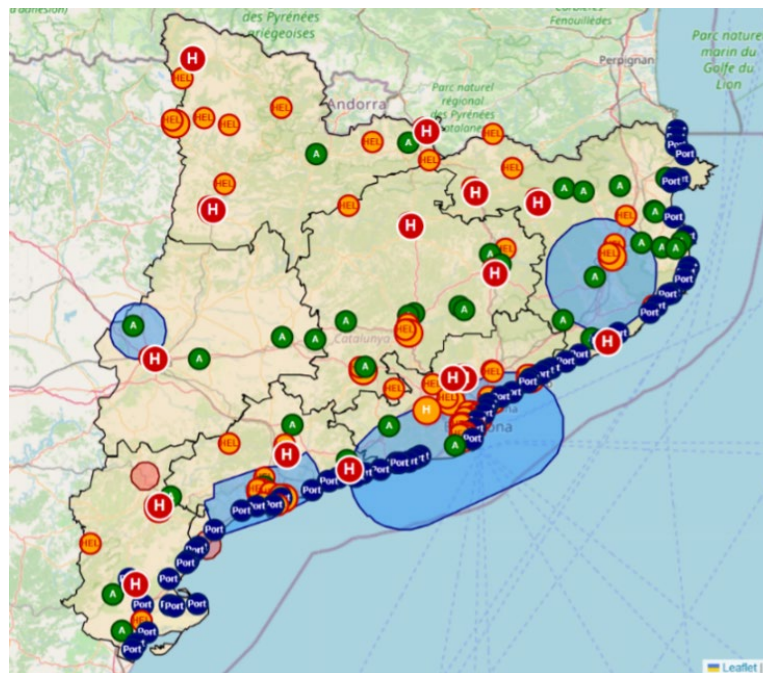


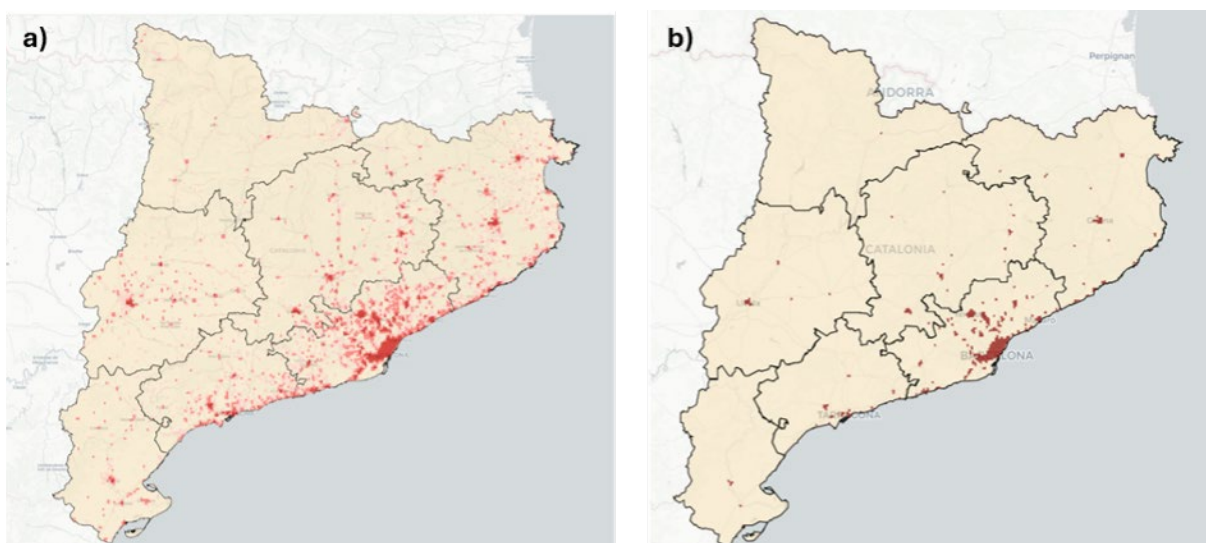
Figure 10. Port, airport and aeronautical infrastructures of Catalonia

4.3. Operational risk indicators

4.3.1 Ground risk (GRC)

To visualize the operational and territorial feasibility of drone operations, two representations of ground risk in Catalonia have

been generated. The first shows the distribution of ground risk (population density in 1 km² sectors) and indicates the health regions and the hospitals located within them. The second image shows the areas where population density exceeds 5,000 inhabitants/km² (Figures 11a and 11b, respectively).



a) Ground risk in Catalonia (inhabitants/km² sectors); **b)** Ground risk (sectors with > 5,000 inhabitants/km²)

Figure 11. Ground risk in Catalonia and areas with population density greater than 5,000 inhabitants/km²

In the second map (Figure 11b), where operationally restricted areas are highlighted, it is shown that only the area surrounding Barcelona, as well as the centers of the main population centers of Catalonia, fall outside the proposed operational scenario.

The operational viability of hospitals in Catalonia has been assessed by combining several key factors: ground risk (GRC), proximity to CTR zones (controlled airspace), and the hospital infrastructure available for drone take-off and landing.

Subsequently, airspace-related criteria linked to CTR zones (controlled airspace) were applied, which limit or prevent certain drone operations (Figure 12).

- Barcelona health region: the presence of the Barcelona CTR excludes most hospitals in the region; only Sabadell and Terrassa remain viable.
- Tarragona health region: the Reus CTR affects the hospitals Joan XXIII, Sant Joan de Reus and Sant Camil; Valls and El Vendrell remain as operational options.
- Girona health region: the Girona CTR excludes Dr. Josep Trueta Hospital and ICO Girona.



Finally, the immediate surroundings of the hospitals were assessed, considering their physical and infrastructure characteristics. At this stage, for example, La Seu d'Urgell is excluded due to the limitations of its urban and topographic environment.

Once all these criteria—ground risk, CTR and infrastructure—have been applied, a total of 15 viable hospitals is obtained where the proposed operations at take-off and landing points do not exceed SAIL III (Figure 13).

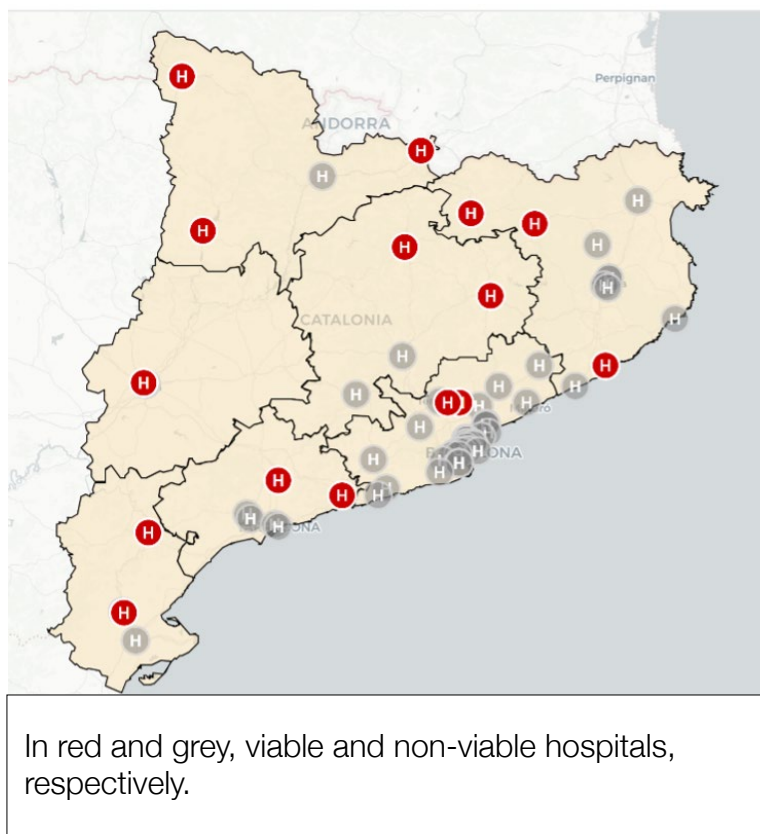


Figure 13. Viable and non-viable hospitals across Catalonia after the implementation of the relevant criteria

In Figure 14, the surroundings of the 15 viable hospitals can be observed, and sectors with more than 5,000 inhabitants/km² that should be avoided in routes defined with origin and destination at these centers are shown, as these are the sectors where drone operations would exceed SAIL III.

It should be noted that in the specific case of

Hospital Verge de la Cinta in Tortosa (Figure 14i), the sector density is 5,009 inhabitants/km². Although it is above the established threshold of 5,000 inhabitants/km², it is located in the part of the sector with lower population density, and the SORA 2.5 methodology allows defining smaller sectors (> 400 m² at maximum altitudes of 305 m AGL and > 200 m² at maximum altitudes of 152 m)².

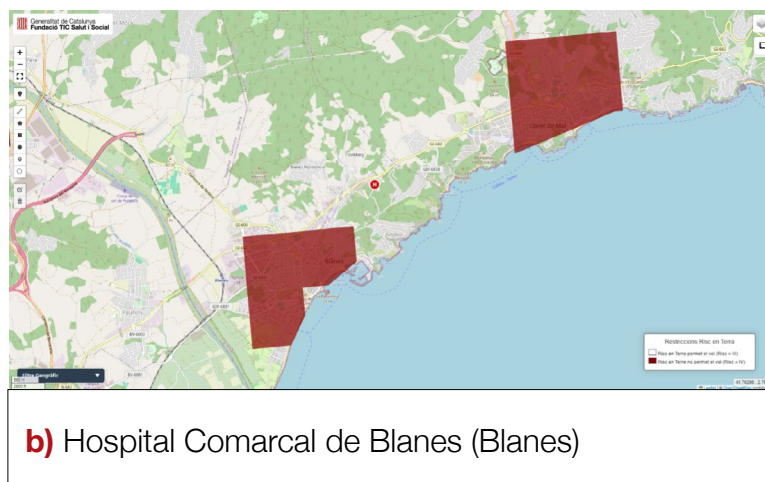
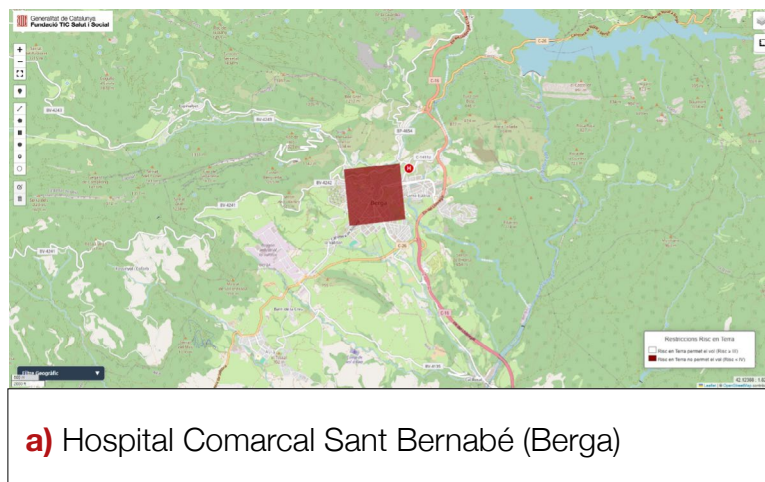
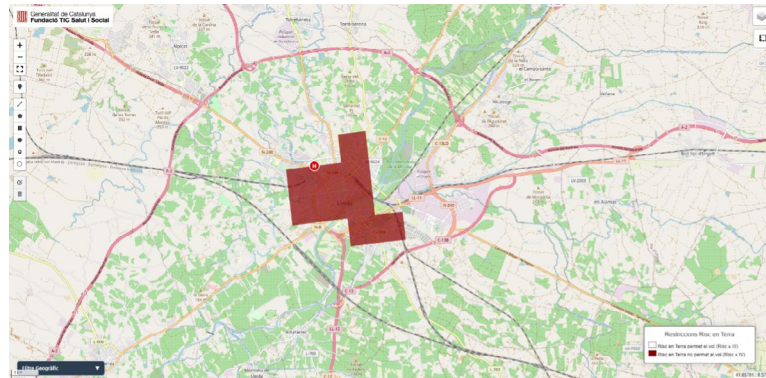
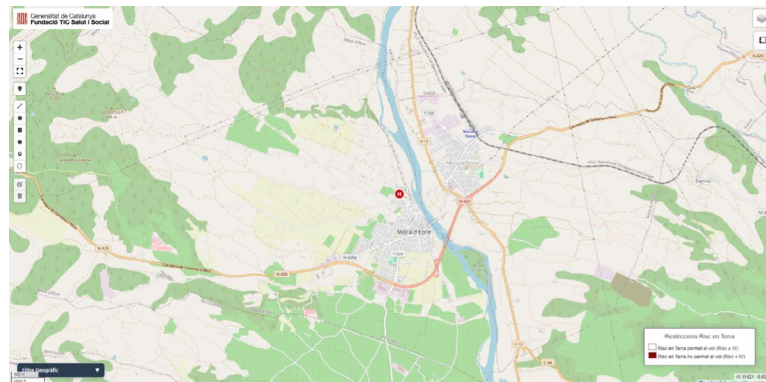


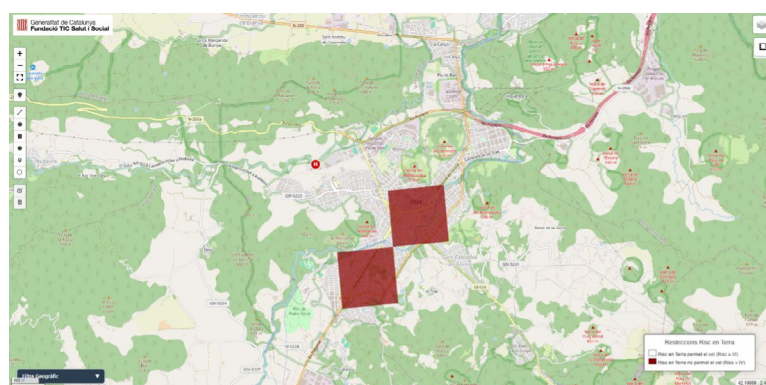
Figure 14. Detailed view of viable hospitals in Catalonia



d) Hospital Arnau de Vilanova (Lleida)

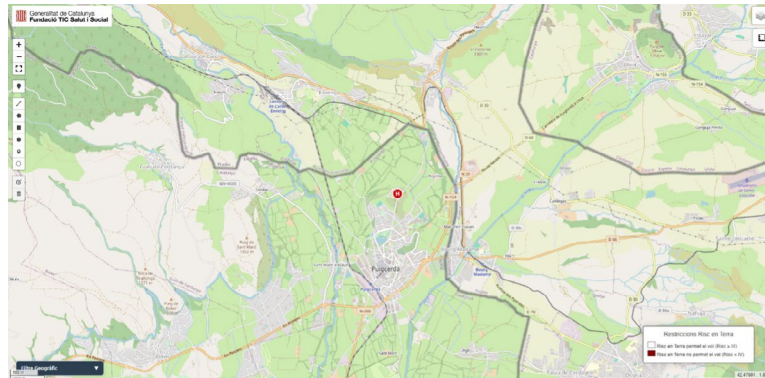


e) Hospital Comarcal de Móra d'Ebre (Móra d'Ebre)

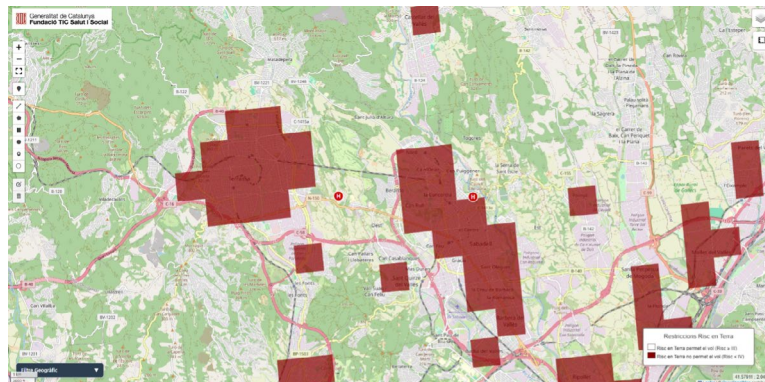


f) Hospital d'Olot i Comarcal de la Garrotxa (Olot)

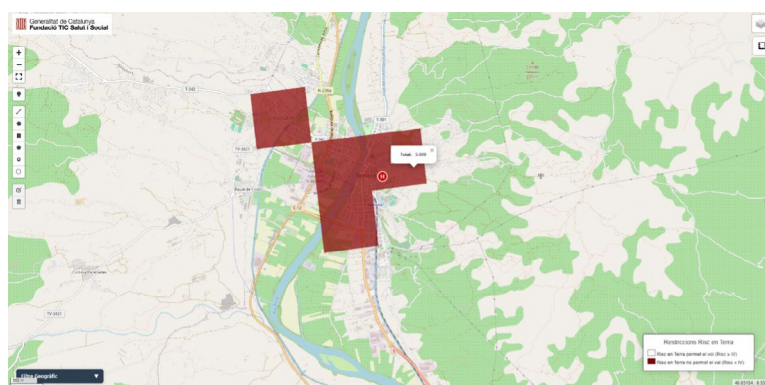
Figure 14. Detailed view of viable hospitals in Catalonia



g) Hospital transfronterer de la Cerdanya (Puigcerdà)

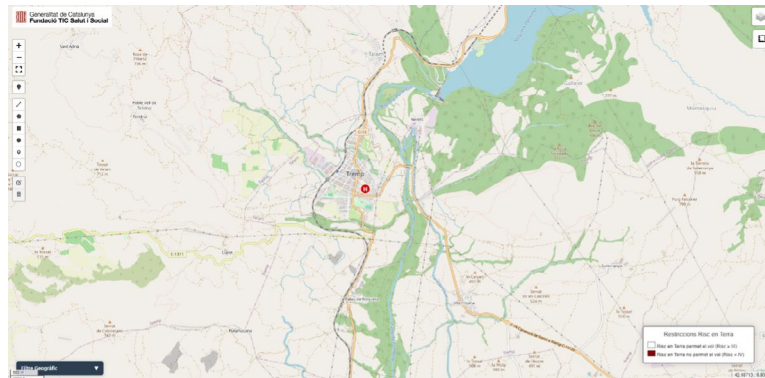


h) Hospital de Terrassa (left) and Hospital de Sabadell (right)

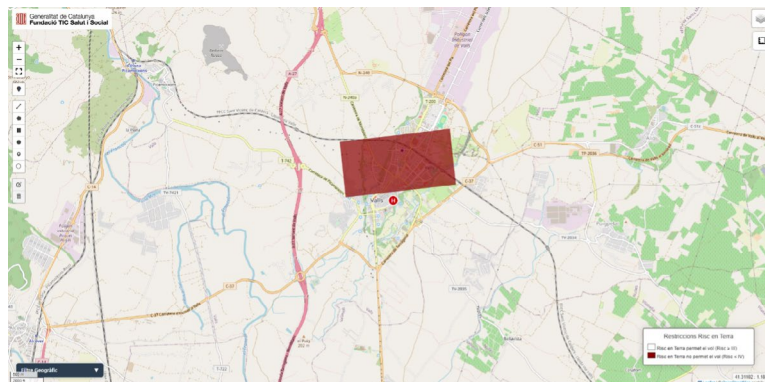


i) Hospital Verge de la Cinta (Tortosa)

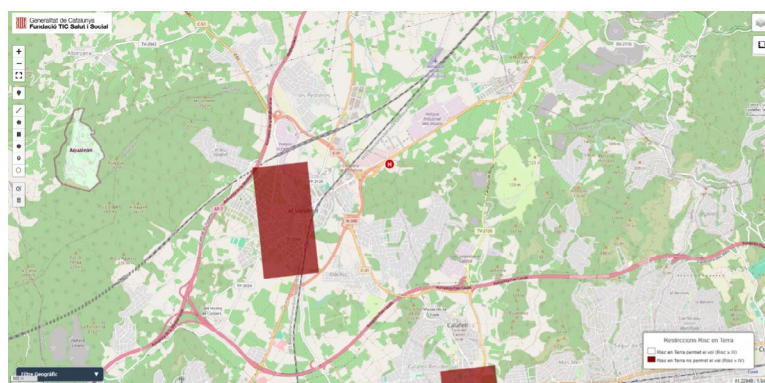
Figure 14. Detailed view of viable hospitals in Catalonia



j) Hospital Comarcal del Pallars (Trepç)

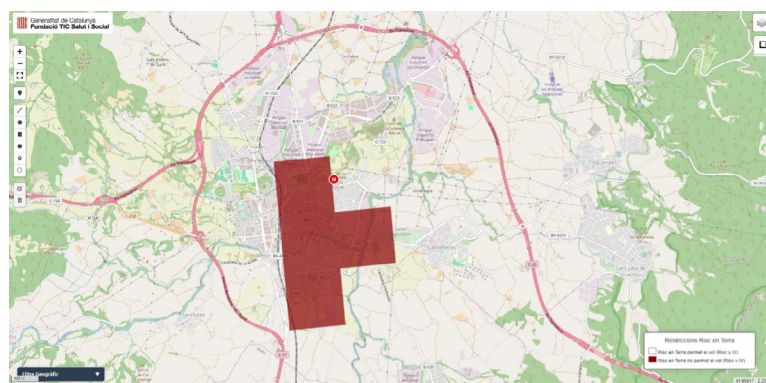


k) PIUS Hospital de Valls (Valls)

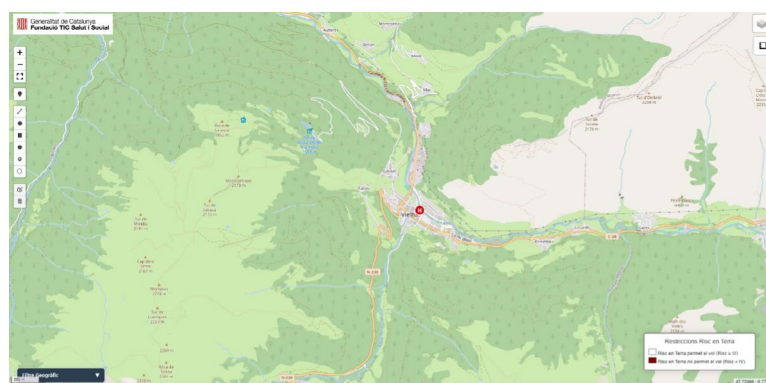


l) Hospital del Vendrell (Vendrell)

Figure 14. Detailed view of viable hospitals in Catalonia



m) Hospital de Vic (Vic)



n) Espitau de la Val d'Aran (Vielha)

Figure 14. Detailed view of viable hospitals in Catalonia

5.

Candidate Areas

After analysing the healthcare, territorial and operational risk dimensions, hospitals located within candidate areas with the most favourable conditions for the deployment of drone routes in the healthcare sector have been identified. These territories combine diverse healthcare environments with favorable geographic and operational contexts, making them strong options for initiating pilot tests.

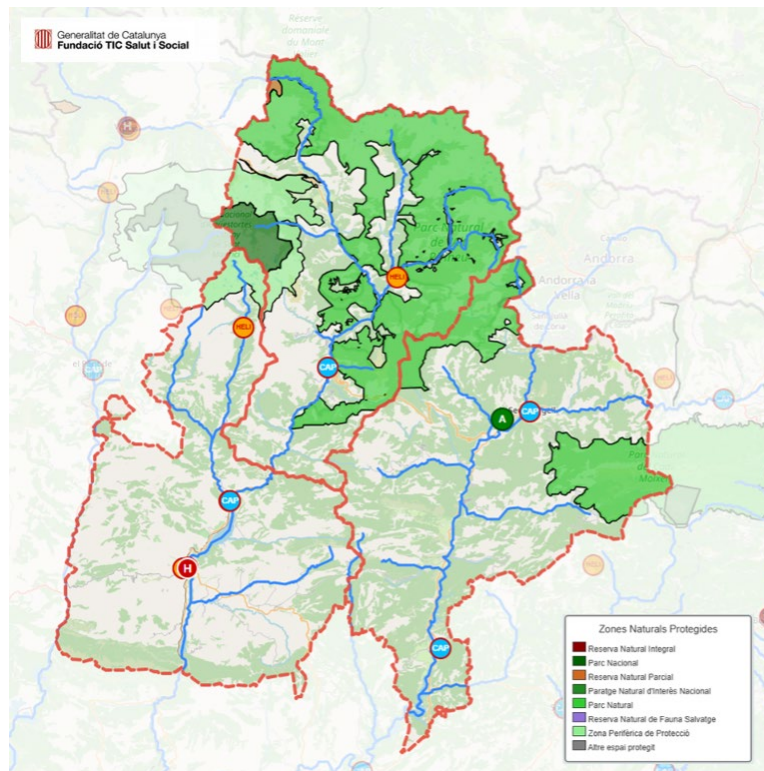
In addition, in the future these areas could become scenarios for the implementation of stable routes addressing specific territorial needs, leveraging drone technology adapted to the particularities of each area (Figure 15).



Figure 15. Heliports and hospitals only (viable)

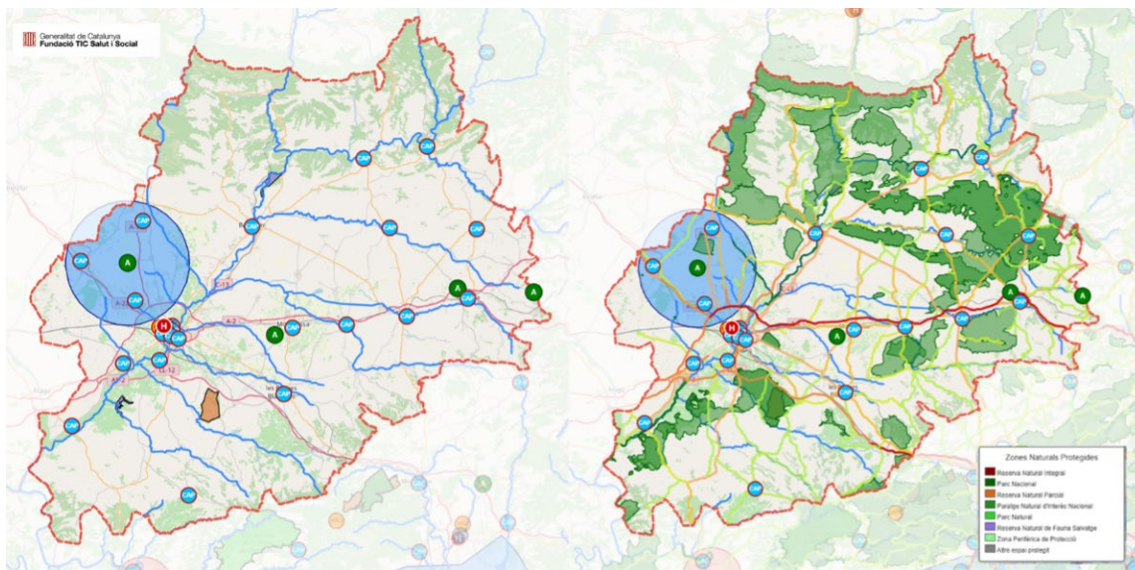
Below, for each candidate region, the geographical location and the main territorial elements associated with drone flight operations are described, including operationally viable hospitals, ground and airport infrastructure, and protected natural areas. Operations may

be carried out in the latter, provided that the proposed operations do not cause disturbance to the protected flora and fauna in the environment.



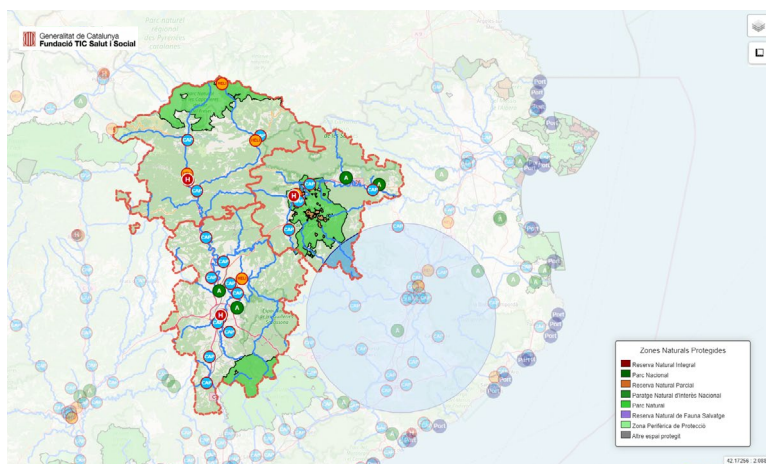
This is a territory with complex terrain and limited accessibility, with two clearly defined zones: the Noguera Pallaresa valley and the Upper Segre. In this region, both the population and healthcare centres are concentrated around rivers, where the terrain is smoother. The use of drones would make it possible to overcome terrain challenges more efficiently than road transport. It also provides an environment for deploying routes during winter periods, making it an ideal scenario to assess whether aerial transport is effective in mountainous areas. In the northern valleys of the Pallaresa, the Aigüestortes i Estany de Sant Maurici National Park and the Alt Pirineu Natural Park are located—two large protected natural areas where operations must coexist with local wildlife. Therefore, it is essential to avoid disturbing protected fauna in these areas.

Figure 17. *Alt Pirineu area*



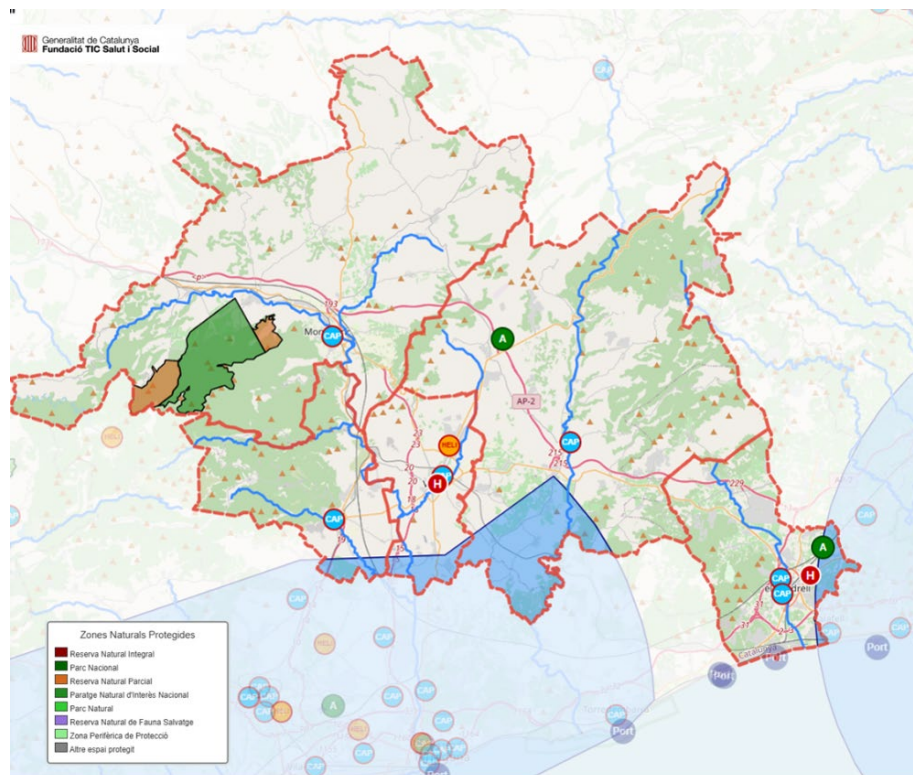
The Lleida plain and the Pla d'Urgell offer a flat area with dispersed population centres where a significant number of routes can be progressively deployed. In addition, the particular location of the Lleida hospital allows operations to be tested in an area with a relatively higher population density. Several protected natural areas are present and must be considered when designing operations to avoid impacting local flora and fauna.

Figure 18. *Lleida*



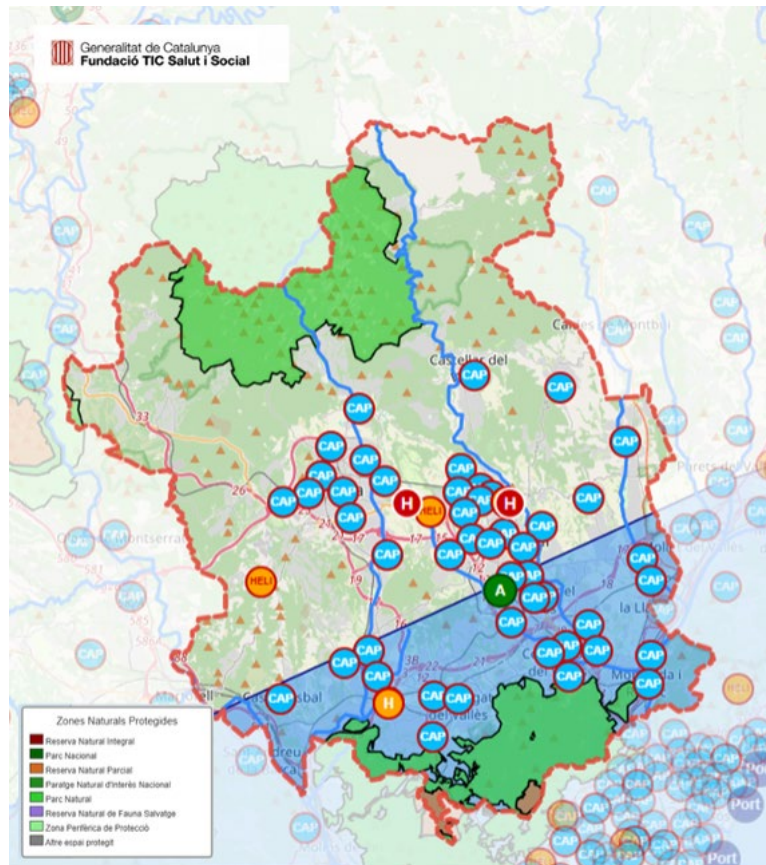
This area features an interconnected healthcare structure and a network of secondary roads. It represents an environment that combines rural areas, such as Garrotxa and Ripollès, with a major communications hub, such as the Vic area. It is an ideal setting for inter-hospital coordination tests connecting two mountain valleys and a plain. In this area, it will be important to ensure that operations respect local flora and fauna, particularly in the Garrotxa Volcanic Zone Natural Park and the Headwaters of the Ter and Freser Natural Area.

Figure 19. Eastern Pre-Pyrenees and Vic Plain (Olot, Campdevàrol and Vic)



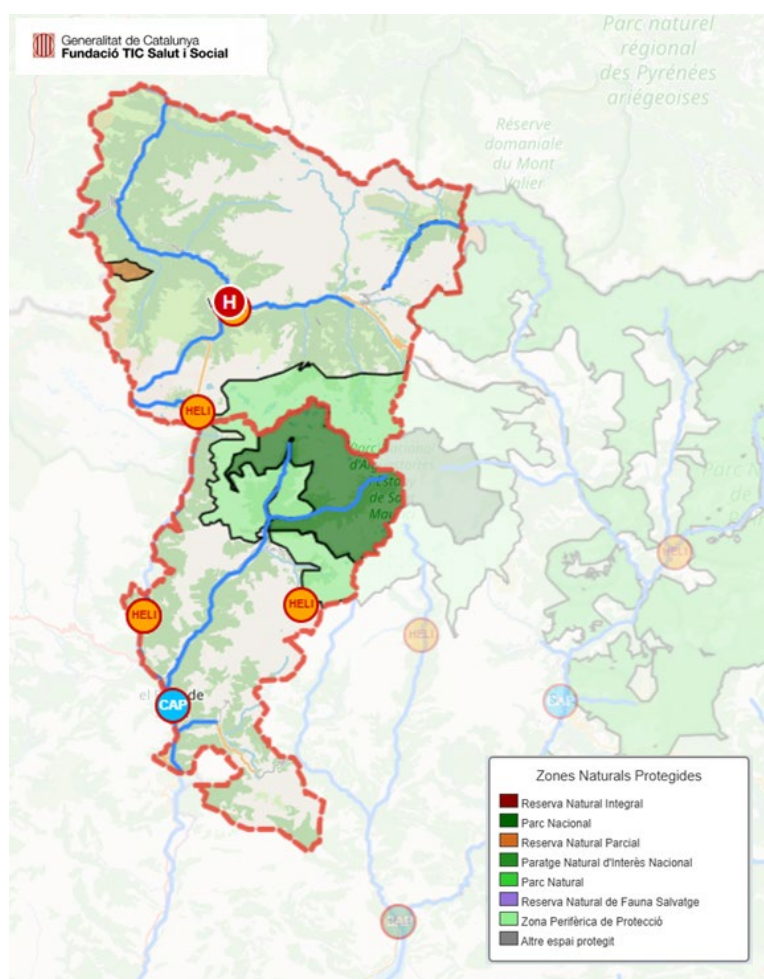
This area is located between two of the most densely populated pre-coastal zones and in an environment influenced by airport CTRs. This strategic location makes it a potential starting point for future drone operations that could progressively expand towards higher-activity corridors, always respecting local flora and fauna.

Figure 20. Valls-Vendrell



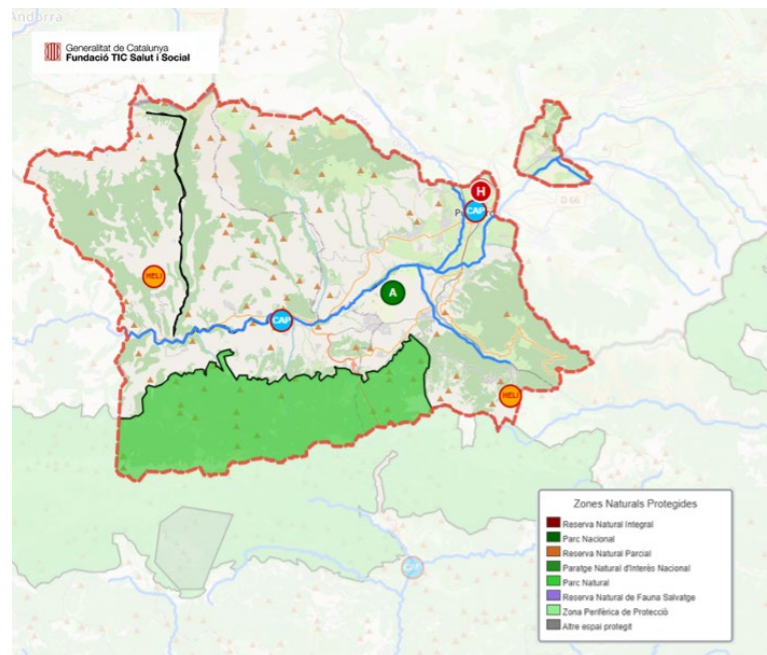
The connection between these two hospitals, and especially the strategic location of Terrassa Hospital, represents a use case that would enable operations to begin between two of the most important urban centres in the Barcelona Metropolitan Area. Additionally, this area could support an aeronautical use case involving operational coordination with Sabadell Aerodrome and the central complex of the Mossos d'Esquadra and its heliport.

Figure 21. *Terrassa-Sabadell*



These two areas are the most remote and hardest to access in Catalonia. From the western side, they are only accessible via the national road that, through Aragón, connects with Lleida; in addition, the Val d'Aran is only accessible via a tunnel. On the other hand, from the east both areas can only be accessed by crossing mountain passes. In potential operations involving local clinics (CL) near the Aigüestortes National Park, operations will need to be compatible with the non-disturbance of local flora and fauna.

Figure 22. Val d'Aran–Pont de Suert



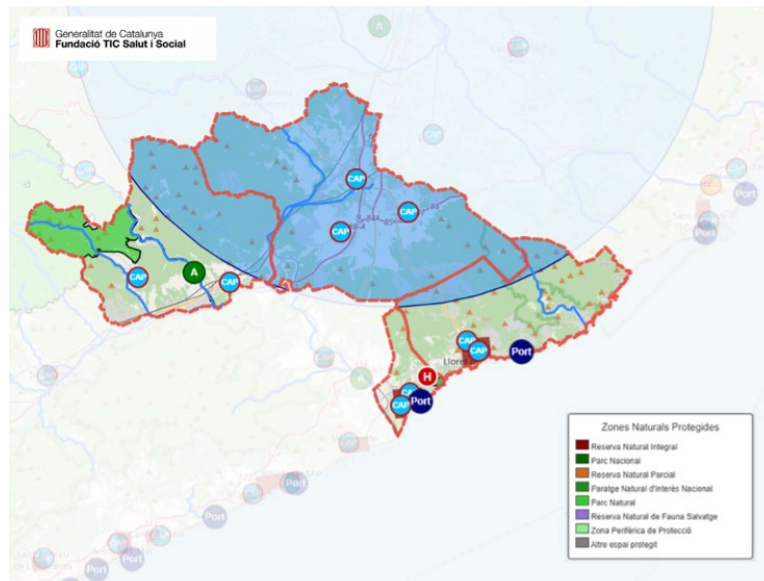
The Cerdanya valley constitutes a wider mountain valley which also has a hospital with good operational conditions. Moreover, from an operational perspective, it would be a candidate area to explore cross-border operations towards French Cerdanya or to connect with other areas further south. It would also allow the exploration of operations under mountain weather conditions. At this point, it is important to take into account the presence of the Cerdanya aerodrome when coordinating operations.

Figure 23. *La Cerdanya*



The Berguedà area is a Pre-Pyrenean region with a significant number of population centres and primary care centres (CAP) that could be connected by operating over the river. It is also important to ensure minimal disturbance to local flora and fauna, especially when operating near the Cadí-Moixeró Natural Park.

Figure 24. *Berga*



The Blanes area, although a relatively small operational area, could provide an opportunity to explore mixed operations or to conduct a pilot test in a limited area. Although the CAPs within the Basic Health Areas (ABS) in this zone are located in areas with high population density, future operations could be considered towards centres located within the area of influence of the Girona–Costa Brava CTR.

Figure 25. *Blanes*

5.1 Healthcare indicators in candidate areas

Although ten viable areas have been identified, for analytical and clarity purposes this report presents three as examples, which could also allow for interconnection between them. These areas are defined as the Terres de l'Ebre area, the Lleida area, and the Alt Pirineu area.

The healthcare structure of Catalonia is composed of an extensive and interconnected territorial network that includes hospitals, primary care centres (CAP) and local clinics. Within the framework of this report, the analysis has focused on reference hospitals and their associated dependent centres (CAP, CUAP and local clinics), as they represent the key points from which most biological samples are generated and transported.

In Catalonia, the Catalan Health Institute (ICS) currently manages a network of public hospitals strategically distributed across the territory, complemented by other publicly funded centres and support facilities that contribute to overall healthcare coverage. These hospitals function as the main logistical nodes within the healthcare network, with multiple associated

dependent centres that channel a significant volume of daily sample requests. Within the target areas, the Arnau de Vilanova Hospital in Lleida and the Verge de la Cinta Hospital in Tortosa are the only ones with fully equipped analysis laboratories and are therefore the destination centres for the transport of certain types of samples from other hospitals.

In order to identify the areas with the greatest potential for the implementation of drone flights, an analysis of the main healthcare indicators has been carried out for the candidate areas derived from the operational and territorial analysis.

In the following sections, the logistical, healthcare and operational coordination indicators specific to each of these three areas will be analysed. This approach allows for a deeper understanding of representative cases that reflect territorial diversity and the different use scenarios for drones in the healthcare sector in Catalonia.

5.2.1 Territorial distribution of hospitals, CAPs and local clinics

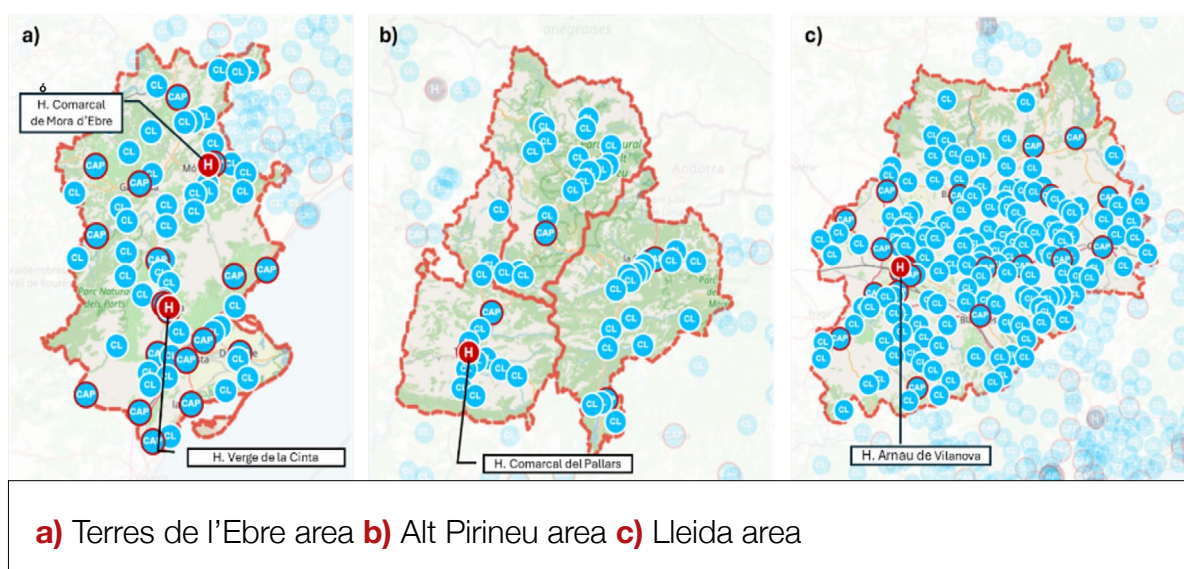


Figure 26. Territorial distribution of hospitals (H), primary care centres (CAP) and local clinics (CL) in the three candidate areas

Table 8 presents a summary of the main indicators per reference hospital in the candidate areas (number of dependent centres per hospital, estimated volume of biological sample requests and intermediate centrifugation centres).

Primary care centres that are functionally dependent on the Sant Hospital de la Seu d’Urgell are also included, even though this hospital is not classified as operationally viable, as they help illustrate the current logistical flow.

The following table shows the distribution of primary care centres dependent on hospitals in the target areas and the number of requests received by the hospitals.

Hospital	CUAP	NO	CL	ABS
Hospital Verge de la Cinta (Tortosa)	0	17	33	9
Hospital Comarcal de Móra d’Ebre	0	3	13	2
Hospital Arnau de Vilanova (Lleida)	1	24	146	24
Hospital Comarcal del Pallars (Trepç)	0	3	30	3
Sant Hospital de la Seu d’Urgell (La Seu d’Urgell)	0	2	21	2

***CUAP** = Primary Care Emergency Centres; **NO** = Primary Care Centres; **CL** = Local Clinics; **ABS** = Basic Health Areas

Table 8. Key indicators by reference hospital

5.2.2 Transport volume and logistics circuits

In healthcare logistics, two distinct transport circuits can be identified: the circuit from primary care to reference hospitals, and the circuit between reference hospitals and hospitals with clinical laboratories.

Table 9 shows the logistics circuits between hospitals in the target areas and the two hospitals that have territorial clinical laboratories: Hospital Verge de la Cinta (Tortosa), which hosts the Terres de l’Ebre territorial laboratory, and Hospital Arnau de Vilanova (Lleida), which hosts the Lleida territorial clinical laboratory.

Hospital with clinical laboratory	Origin hospitals	Type of biological sample	Monthly average
Hospital Verge de la Cinta (Tortosa)	Hospital d'Amposta	Laboratory tests	21
		Pathology studies	54
	Hospital Comarcal de Móra d'Ebre	Laboratory tests	2
		Pathology studies	313
	Clínica Terres de l'Ebre (Tortosa)	Laboratory tests	8
		Pathology studies	10
	Hospital de la Santa Creu - Internament (Jesús)	Laboratory tests	130
		Dialysis laboratory tests	149
Hospital Arnau de Vilanova (Lleida)	Hospital Comarcal del Pallars	Blood and urine samples	589
		Pathology samples	5-7
	Sant Hospital de la Seu d'Urgell	Routine pathology samples	20
		Other routine samples	27

*AP = Pathology (anatomical pathology)

Taula 9. Logistics circuits between target hospitals and hospitals with clinical laboratories

In the case of the Terres de l'Ebre area, the clinical laboratory at Hospital Verge de la Cinta receives samples and pathology studies from all hospitals in the area and, although some sample requests are transported between hospitals, the main volume of inter-hospital transport corresponds to pathology studies.

In the case of the Lleida and Alt Pirineu areas, Hospital Arnau de Vilanova hosts the clinical laboratory for both areas and acts as the reference analysis centre for hospitals in Tremp

and La Seu d'Urgell for different types of samples, beyond the collection of blood, stool and urine samples.

Table 10 shows the average number of daily requests received by ICS clinical laboratories during May 2025. This data allows us to estimate the volume of requests generated in the different areas.

Clinical laboratories	No. requests/day
Laboratori Clínic Metropolitana Nord (H. Germans Trias)	3.110
Laboratori Clínic Territorial Girona (Parc Sanitari Martí Julià)	2.187
Laboratori Clínic Territorial Lleida (H. Arnau Vilanova)	1.630
Laboratori Clínic Territorial Metropolitana Sud (H. Bellvitge)	3.209
Laboratoris Clínic Camp de Tarragona-Terres de l'Ebre (H. Joan XXIII)	1.194
Laboratoris Clínic Camp de Tarragona- Terres de l'Ebre (H. Verge de la Cinta)	610
Laboratoris Clínic Vall d'Hebron	3.213
Total	15.153

Taula 10. List of ICS clinical laboratories

Regarding logistics circuits between primary care centres (e.g. CAP and CUAP) and hospitals, each area is analysed separately, as each has a different logistics model. For each circuit, both the number of test requests from primary care and the number of containers collected are analysed.

Lleida area

Hospital Arnau de Vilanova (Lleida) is the hospital with a clinical laboratory that receives requests from all basic health areas (ABS) in the Lleida health region. As mentioned, this region has a very high number of centres (171 centres including CAP, CUAP and CL), with the most distant centres located up to 80 km from the hospital and travel times close to one hour. Since many samples collected at primary care centres can remain stable for up to approximately two hours, collection routes

from the most remote ABS in Lleida become complex. These two hours represent the time window during which a collected sample can remain stable without degradation affecting key quality parameters and altering the original clinical values (e.g. potassium, glucose or degree of haemolysis).

To address this logistics issue, **centrifuges** were installed at CAPs in rural ABS, outside the urban primary care teams in Lleida, as well as at CAPs in the southern and northern rural ABS close to Lleida. Table 11 shows the daily sample volume in May 2025 and the number of centrifuges in EAPs that have Hospital Arnau de Vilanova (Lleida) as their reference laboratory.

Destination hospital	Primary Care Team (EAP)	Average requests/day	Centrifuges
H. Arnau Vilanova	EAP Agramunt	32	1
	EAP Alcarràs	72	1
	EAP Alfarràs - Almenar	71	2
	EAP Almacelles	50	1
	EAP Artesa de Segre	19	1
	EAP Balaguer	127	2
	EAP Bellpuig	26	1
	EAP Cervera	56	2
	EAP Guissona - La Segarra	42	1
	EAP La Granadella	14	1
	EAP Les Borges Blanques	77	1
	EAP Lleida 1- Centre Històric - R. Ferran*	79	0
	EAP Lleida 2 - Primer de Maig*	103	0
	EAP Lleida 3 - Eixample*	99	0
	EAP Lleida 4 - Balàfia - Pardinyes*	116	0
	EAP Lleida 5 - Cappellet*	73	0
	EAP Lleida 6 - Bordeta - Magraners*	114	0
	EAP Lleida 7 - Onze de Setembre*	73	0
	EAP Lleida Rural 2 - Sud	37	0
	EAP Pla d'Urgell (Mollerussa)	196	1
	EAP Ponts	20	1
	EAP Seròs	27	1
	EAP Tàrraga	89	3
	EAPT Lleida 1	19	0
Total		1.629	20

*Urban **EAPs** in Lleida

Table 11. Daily sample volume in May 2025 and number of centrifuges in primary care teams (EAP)

Alt Pirineu area

In the case of the Alt Pirineu area, it is important to note that, due to the orographic characteristics of the region, it has been divided

into three distinct zones corresponding to the three valleys of the western Pre-Pyrenees, each with a reference hospital:

Geographical area	Destination hospital	ABS
Alta Ribagorça	Espitau de la Val d'Aran	Alta Ribagorça
Pallars	Hospital Comarcal del Pallars	Pallars Sobirà, la Pobla, Tremp
Alt Urgell	Sant Hospital	La Seu d'Urgell i Alt Urgell sud

Table 12. Table 12 title

In the case of centres and EAPs in Alt Pirineu, a specific situation should be highlighted. Due to the low population in some areas and the wide dispersion of centres, some CLs send samples in very small volumes. Therefore, the transport of CAPs and CLs that regularly send samples and generate requests to their reference centres is detailed below.

Shipments to Hospital Comarcal del Pallars

In the case of Pallars, the following container volumes are transported from the main collection centres:

Centre	ABS	No. samples/month	No. transports/week	Average samples/day*
CL Esterri	Pallars Sobirà	270	3	22
CL Llavorsí		207	3	17
Cap Sort		919	3	76
CAP Pobla	La Pobla	795	3	66
CAP Tremp	Tremp	1.307	5	65

*Average number of samples per transport day

Table 13. Container volumes

Shipments to Sant Hospital de La Seu d'Urgell

For the Alt Urgell area, Table 14 details the primary blood and urine samples collected

at the centres and sent to Sant Hospital throughout 2024.

Centre	ABS	Samples tubes 2024	Average tubes
CAP La Seu d'Urgell	La Seu d'Urgell	24.782	2.065
CL Martinet		1.181	98
CL Tuixent		133	11
CAP Oliana	Alt Urgell sud	4.018	334
CAP Organyà		1.614	134
CL Coll de Nargó		987	82

Table 14. Primary blood and urine extractions sent to Sant Hospital

Terres de l'Ebre area

In the case of the Terres de l'Ebre area, Hospital Verge de la Cinta collects requests and samples from 8 of the 11 ABS in the Terres de l'Ebre

health region. The table below shows the volume of requests generated.

Destination hospital	Primary Care Team (EAP)	No. tests (Jan-Sep)	Monthly average
H. Verge de la Cinta	EAP L'Aldea - Camarles - L'Ampolla	8.084	898
	EAP L'Ametlla de Mar - El Perelló	5.470	608
	EAP Amposta	15.046	1.672
	EAP Deltebre	8.835	982
	EAP Sant Carles de la Ràpita	15.059	1.673
	EAP Ulldecona	6.327	703
	EAP Tortosa 1 Est - El Temple	9.874	1.097
	EAP Tortosa 2 Oest	13.149	1.461

Taula 15. Requests collected by Hospital Verge de la Cinta

5.2 Logistics indicators for the candidate areas

Once the priority areas had been defined, key logistics indicators were analysed to assess the potential efficiency of drone transport compared to conventional road transport.

To contextualise this analysis, a layer was created in the interactive map integrating information on main, secondary and regional roads. Figure 27 shows an image of the main motorways and national roads.

*H = Hospitals



Figure 27. Map of main roads in Catalonia

This cartographic layer, available in the project's interactive map, makes it possible to identify sections with greater complexity for ground transport and, therefore, those where the use of drones may provide greater operational benefit. Figure 28 shows the three target areas,

including the main roads passing near the viable hospitals, which would therefore be the destinations of biological sample collection routes.

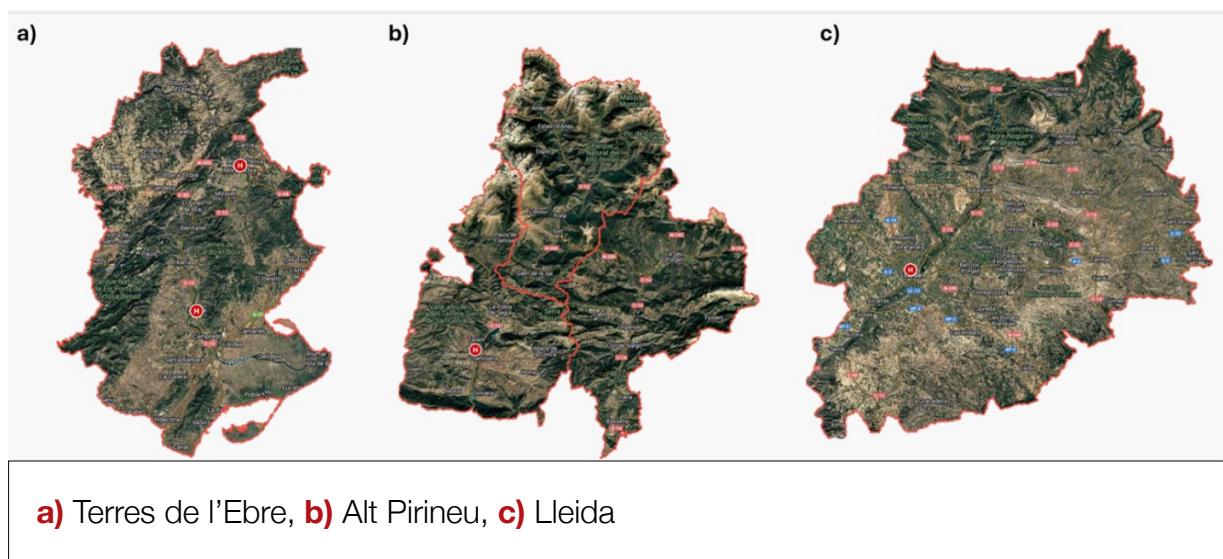


Figure 28. Candidate areas – main roads

Terres de l'Ebre area

In this area, the main national and regional roads are the C-12, N-420 and E-15. The main route analysed is the C-12, as it connects towns with hospitals and CAPs in the Ribera d'Ebre. The route studied runs from CAP Flix, the northernmost CAP in the area, via Hospital de Móra la Nova, to CAP Amposta, where the C-12 connects with the E-15 (Figure 26a).

For the E-15, the section between Amposta and Uldecona was considered, where the last CAP is located before entering the Valencian Community.

Additionally, the N-230 crosses the territory from west to east. In this case, the section linking CL Caseres, west of the Terra Alta EAP, with CAP Gandesa and onwards to Móra la Nova and Móra la Vella was analysed.

Finally, two sections of regional roads were considered:

- The T-703/C-333 between CAP Flix and CL Margalef, representing the regional road network in the upper Ribera d'Ebre, which connects with Les Garrigues
- The TV-7231 between CAP Gandesa and CL La Pobla de Massaluça, representing local roads in Terra Alta, the most irregular terrain within the Terres de l'Ebre area

Alt Pirineu area

In this area, it is particularly relevant to analyse the two roads connecting the hospitals of Tremp and La Seu d'Urgell with Lleida, where the reference laboratory is located: the C-12 and the C-14.

The route between Tremp and Senet was also considered, covering a section of the C-13 to La Pobla de Segur, the Pyrenean axis (N-260) and the N-230, as an example of a mountain road route. Although these are national roads, they traverse irregular terrain and mountain passes (such as the Perves pass) on the route to Pont de Suert and onwards to CL Senet, the last clinic before the Vielha tunnel. The Tremp-Sort section of the N-260 has also been included, as it is the road that connects the CAPs of Pallars.

Regarding the regional road network, the C-1412b was considered, which connects to CL Isona and serves as an access route for vehicles travelling from Tarragona or Barcelona towards Tremp. Finally, the LV-5212 and L-500 roads were included as examples of routes connecting a major population centre (Pont de Suert) with CLs in mountain valleys (Figure 26b).

Lleida area

In this area, the main route is the A-2 motorway, which connects Lleida with the main towns in Urgell and Segarra, all of which have CAPs. For this reason, the section up to CAP Cervera was considered.

Secondly, a section of the N-240 between Lleida and CL Vinaixa was analysed. This is the national road connecting Lleida with CAP Les Borges Blanques and extending to the most distant CL along this route. From this road, several routes branch off towards the northern part of Les Garrigues.

Regarding regional roads, the upper section of the C-12 between Lleida and Maials was analysed, as it connects clinics in the southern Segrià area. The C-242, which links to CAP La Granadella and the southern part of Les Garrigues, was also included.

Finally, the C-233 between Bovera and Juncosa was considered as a representative example of a regional road in a predominantly rural area (Figure 26c).

The sections analysed across the three areas represent the main connections between hospitals and dependent centres within the candidate areas and form the basis for the following analysis.

5.2.1 Distance and average time

This section compares travel time graphs for the different road segments, as well as the percentage difference between drone travel time and van travel time. This approach makes it possible to identify not only absolute variations but also the relative magnitude of time savings across each territory and the average across the three areas:

43,63%

Reduction
Lleida

49,21%

Reduction
Alt Pirineu

54,94%

Reduction
Terres de l'Ebre

49,04%

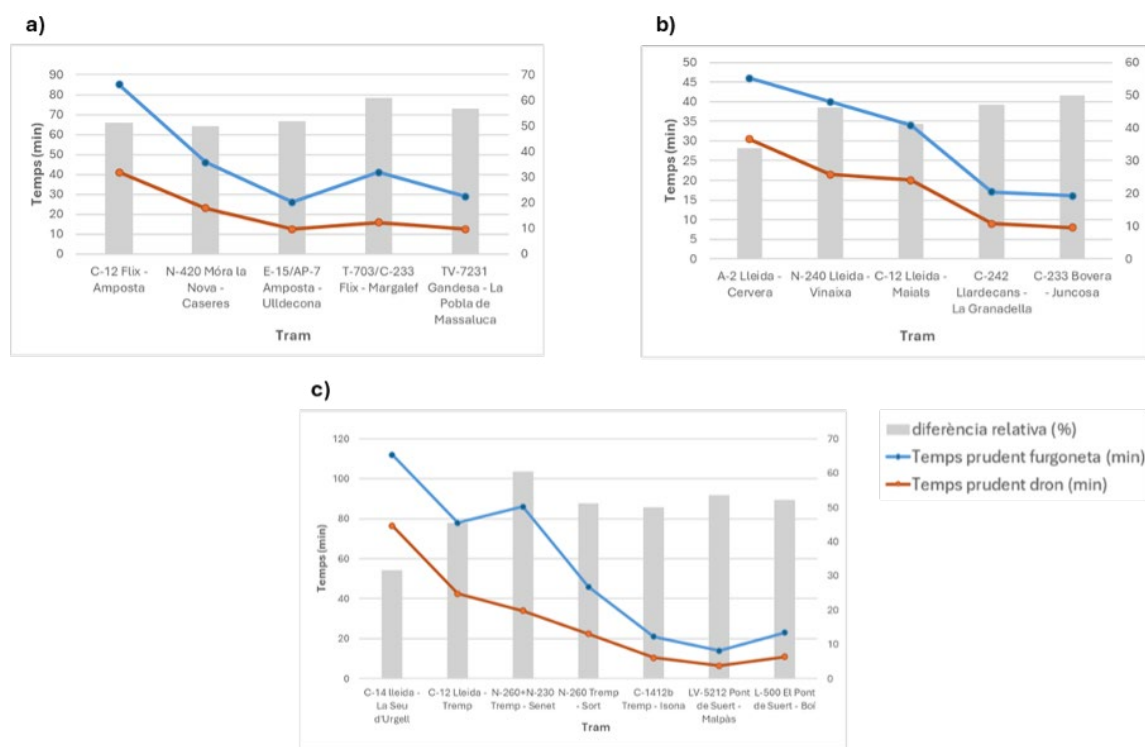
Average
reduction

If journey times across all areas are analysed, the highest values correspond to the Pyrenees area, particularly on the routes connecting Lleida with the towns that have hospital centres (Tremp and La Seu), on the one hand, and the routes between TrEMP and the most distant local clinics (CL) associated with the Hospital Comarcal del Pallars, on the other. These long distances reflect the dispersion of healthcare centres in the Alt Pirineu area (Figure 29c).

It is also noteworthy that in the Lleida area there is little difference in time reductions between main and secondary regional roads (Figure 29b).

By contrast, in the Terres de l'Ebre area there is a greater difference between main national/regional roads and secondary regional roads. It is also worth noting the difference observed in motorways:

the A-2, which connects Lleida with Barcelona and extends towards Aragón, shows the smallest difference compared to drone transport, whereas the AP-7, which runs along the coast and has much higher traffic density, shows time savings similar to those of other national and regional roads (Figures 29b and 29a, respectively).



a) Zona de Terres de l'Ebre, **b)** Zona de Lleida, **c)** Zona de l'Alt Pirineu

Figure 29. Graphs of the time difference between a van and a drone

5.2.2 CO² emissions of the service (comparison between a van and a drone)

The comparative analysis of CO² emissions between road transport (diesel vans) and delivery drones—powered by different electricity sources (coal, natural gas and renewables)—shows very significant differences in carbon footprint. Currently, diesel vans used for short-range healthcare transport emit between

120 and 220 g of CO² per kilometre (g/km), depending on speed and traffic conditions.

By contrast, an electric drone produces much lower emissions, even when electricity is generated from fossil fuels. Depending on the electricity generation source, emission reductions would be as follows:

92%-96%

Coal-based generation

95,5%-97,6%

Natural gas generation

49,04%

Renewable energy generation

The comparison of CO² emissions between diesel vans and the different drones can be seen

in Figure 30.

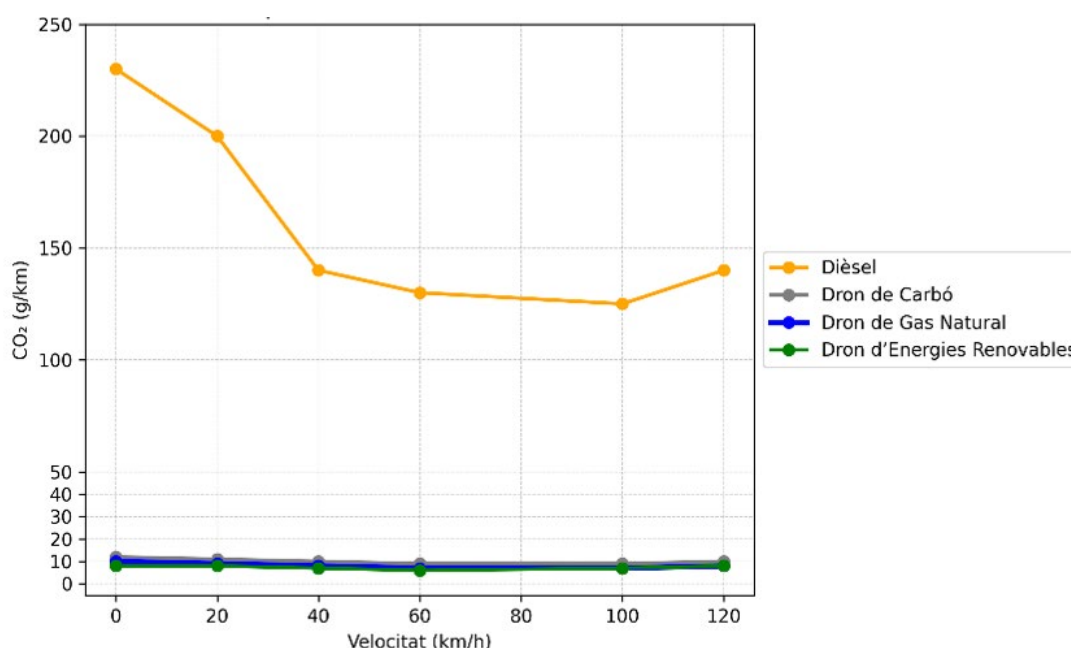


Figure 30. CO² emissions comparison

5.2.3 Cold chain and transport temperature

To ensure the quality of biological samples during transport, maintaining the cold chain is essential. In this regard, tests carried out using the packaging—capable of holding approximately 600 g of samples—have demonstrated high thermal stability under real drone transport conditions.

With an average external temperature of 20 °C, the packaging maintained the internal temperature within the 2 °C – 8 °C range for approximately 26 hours. The time distribution across intervals was as follows:

- 2 °C – 3.5 °C: 2 hours
- 3.5 °C – 5 °C: 4 hours
- 5 °C – 6.5 °C: 17 hours

These results can be seen in Figure 31, which shows the stability of the packaging system over time. This graph shows that the packaging allows the temperature of the samples to be maintained within the time range established in the technical specifications and could also maintain temperature ranges for samples at ambient temperature (8 °C – 21 °C) and refrigerated (2 °C – 8 °C).

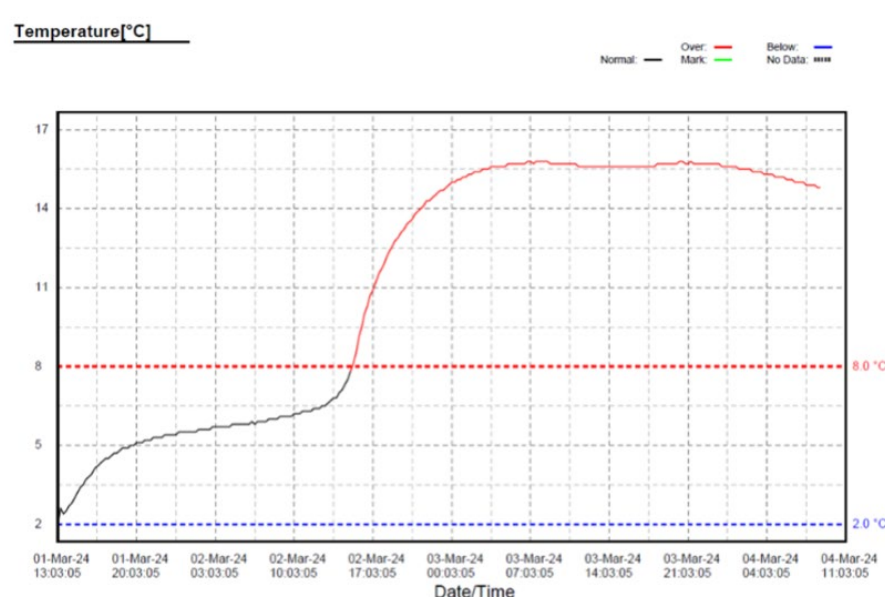


Figure 31. Temperature analysis

5.3 Coordination actions and operational authorisation

To ensure safety and the orderly integration of UAS operations within the designated airspace, a series of administrative procedures (communications, declarations and coordination actions) must be carried out to ensure that the proposed flight operations are conducted in accordance with regulations, as requested and, above all, safely. In this regard, it is important to distinguish between actions related to the formal authorisation of the flight prior to the start of operations and operational coordination actions carried out in real time during the operation.

To illustrate the stakeholders involved in these two processes, screenshots from the interactive map of the Fundació TIC Salut i Social are provided for the target areas, showing the stakeholders involved in the request and granting of operational authorisation and in operational coordination. This visualisation facilitates the identification of the main stakeholders in the areas or sectors where the proposed routes are located, who must be informed and/or notified of the operation.

It also enables the identification of potential airspace conflicts, restrictions and entities with which coordination is required. It should also be noted that, at the time of coordination, the

specific characteristics of each operation must be assessed, as they may not be represented. The stakeholders and areas where authorisation must be requested, as well as those where operational coordination must be carried out, are analysed below.

5.3.1 Operational request and authorisation

In the current operational scenario, work is carried out under operational authorisations that segregate the airspace forming the drone's flight geography and the contingency volume defined for the operation. This includes all those territorial elements where drone operations are restricted or conditioned by safety rules, environmental protection or aeronautical regulations. These elements have been represented in combination with the sectors exceeding 5,000 inhabitants/km² corresponding to each candidate area. The factors analysed are:

- Protected parks, zones and natural areas
- Police bases and infrastructure (Mossos d'Esquadra, local police, Guardia Civil, National Police)
- Other areas where operations are regulated and require prior communication and/or authorisation, such as urban environments, protection zones for railway and port infrastructure, protected natural areas, etc.

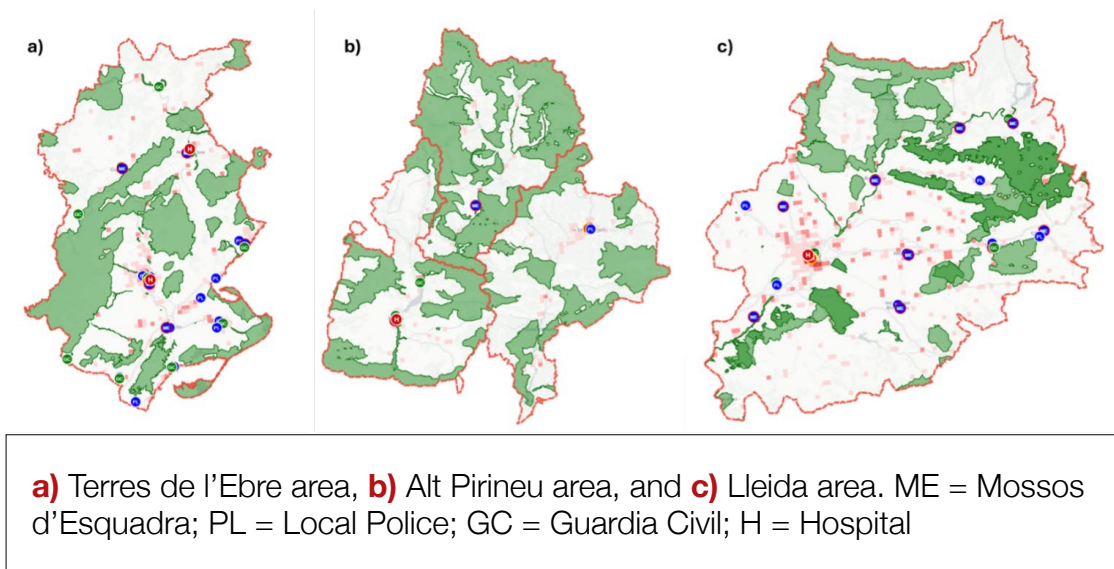


Figure 32. Map of infrastructure and natural areas requiring operational authorisation

5.3.2 Operational coordination

This includes infrastructure that, although not requiring formal authorisation, requires prior coordination to avoid operational interference with critical services. In this case, the factors analysed are:

- Commercial and recreational ports
- Controlled airspace (CTR)
- Safety zones of aerodromes and heliports, including SEM bases and heliports

This information is essential to determine the actual operational feasibility of each candidate area and to define flight routes and protocols that minimise risks and ensure integration with existing services.

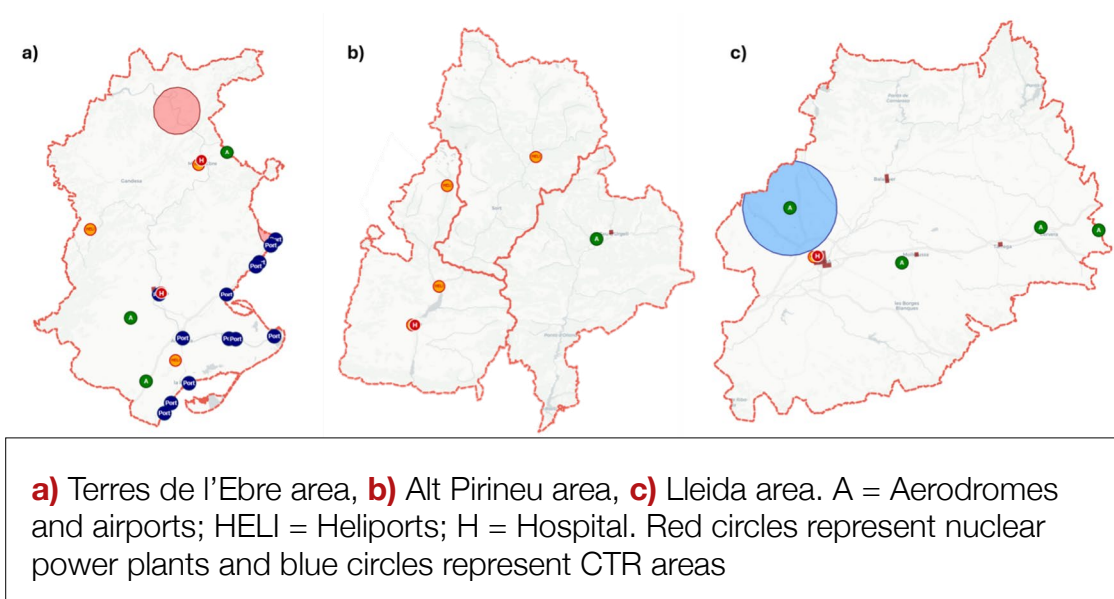


Figure 33. Infrastructures that require operational coordination

6.

Discussion

This report has analysed the feasibility of integrating the use of drones into healthcare logistics operations within the Catalan healthcare system (SISCAT). The study combines demographic, geographical, aeronautical and healthcare-related information with the aim of characterising risk, identifying potentially operational hospitals, and determining the areas with the greatest feasibility and impact for the deployment of drone routes. Accordingly, the objective has been to establish to what extent the existing infrastructure, the distribution of ground risk and airspace restrictions allow for the development of safe and efficient operations, while also identifying the main territorial and logistical challenges to be considered in future design and deployment phases.

The territorial analysis of SISCAT reveals significant heterogeneity across regions. Catalonia comprises ten healthcare regions with widely varying population densities, urban structures and aeronautical conditions, which strongly influence the feasibility of drone flights. The three most densely populated regions — Barcelona city, Metropolitan North and Metropolitan South — present the main obstacles: high urban density and the extensive presence of the Barcelona airport CTR. Nevertheless, there are specific exceptions, such as Hospital de Terrassa, located in an area with lower population density and with potential connectivity to Sabadell.

In the case of Camp de Tarragona, urban concentration around Tarragona and Reus and the influence of the Reus airport CTR considerably limit operational feasibility, whereas more inland areas, particularly around Valls and its hospital, appear viable. Intermediate situations can be found in the Penedès and Girona healthcare regions, which combine areas with high density or aeronautical restrictions (Alt Penedès, Garraf, Gironès, Pla de l'Estany, part of La Selva and Empordà) with operationally favourable areas such as Baix Penedès, Blanes, Ripollès and Garrotxa.

Central Catalonia stands out for its generally good viability, except for the more densely populated area of Manresa, and allows for the planning of stable routes from hospitals such as Berga or Vic. The Terres de l'Ebre region also presents a favourable context:

the coastal plain and the Ebro valley facilitate operational corridors from Tortosa to Móra d'Ebre. Similarly, the Lleida healthcare region, despite population concentration in the capital, has an extensive plain highly suitable for BVLOS routes connecting a large number of centres. Finally, the Alt Pirineu and Aran region, with the lowest population density in the country, shows the greatest potential for clinical and logistical benefit, as its complex terrain and long distances make road transport particularly challenging.

These territorial elements have direct implications for healthcare logistics. Areas with lower hospital density depend on smaller healthcare facilities located further from reference laboratories, which increases transport times and variability in service response. Drones become particularly relevant in territories with complex terrain, limited road networks or highly dispersed populations — such as inland plains or mountainous areas — where they can significantly reduce journey times and improve service regularity.

The assessment of operational risk confirms that a large part of Catalonia presents conditions compatible with BVLOS operations. Only very densely populated areas — mainly the Barcelona Metropolitan Area and some coastal urban centres — exceed the density thresholds that place operations outside a SAIL III scenario. The rest of the territory, including most of Central Catalonia, inland Girona, western Catalonia, the Ebro region and much of Camp de Tarragona, is largely favourable for safe drone operations.

Integrating these criteria with the location and physical characteristics of hospitals makes it possible to narrow down the initial set of options to 15 truly viable hospitals. This group constitutes the primary territorial basis for future deployments, as it ensures approach and take-off operations in areas with fewer than 5,000 inhabitants/km² and outside major aeronautical restrictions.

The logistical study carried out in the candidate areas shows that the use of drones could result in a reduction in transport time of between 20% and 60%, along with a reduction in CO₂ emissions of up to 99.8% in the case of electrically powered drones.

Furthermore, it is essential to use packaging that ensures sample stability within the ambient temperature range (8–21 °C) and refrigerated range (2–8 °C) for up to 2 hours. This stability is particularly important for transporting sensitive samples, such as blood or pathology samples, which require strict temperature control to maintain diagnostic validity.

Overall, the analysis carried out in this report confirms that Catalonia presents a combination of territories where drone operations are both technically feasible and clinically relevant, in line with the healthcare needs of SISCAT, the territorial structure and operational risk. The alignment between clinical demand, actual distances, terrain and aeronautical safety conditions creates a broad set of candidate corridors and hospitals where drone transport could provide tangible benefits in terms of speed, reliability and territorial equity. This feasibility framework allows progress towards more detailed planning and the specific assessment of priority areas, where the potential impact of deployment can be evaluated more precisely. However, further progress requires addressing several structural challenges that will shape the gradual integration of drones into the healthcare environment. Although technical feasibility and initial adoption have already been demonstrated in several centres in Catalonia, stable and systematic deployment requires the development of dedicated UAS infrastructure integrated into hospital logistics circuits. Current pilot trials — limited in time and based on temporary take-off and landing elements — have highlighted the need for permanent infrastructure integrated with healthcare centres, enabling the incorporation of the transport of samples, medication and medical supplies into routine healthcare and logistical workflows. These infrastructures are essential for UAS operators to provide the services required to maintain drone operations, such as maintenance, minor repairs, component replacement and battery recharging or power supply management.

In addition, administrative procedures remain a significant barrier, and progress towards a single-window model would be necessary to simplify and accelerate procedures associated with drone operations in the healthcare sector. Likewise, to ensure the sustainability of the model and reduce personnel-related operational

costs, it is essential to move towards remote assistance systems and digital platforms that allow logistics management to be largely automated, while maintaining required safety standards.

The integration of drones into the healthcare environment represents the creation of a new business and logistics model within the healthcare sector, with significant potential to improve emergency response and to make the current healthcare transport model more sustainable and environmentally friendly. To ensure that efficiency gains and cost reductions become a reality, automation will be one of the key areas in which the unmanned aviation sector will continue to evolve in the coming years. The introduction and deployment of U-Space services, together with other enabling technologies such as high-capacity, low-latency telecommunications, artificial intelligence and cybersecurity, should allow drone operations to scale, enabling the remote management of multiple aircraft simultaneously and making services that began as pilot projects economically viable. Within this framework, experimental environments — also known as sandboxes, i.e. controlled environments designed to test new technologies and urban air mobility services prior to large-scale deployment — will enable regulatory adaptation and flexibility based on empirical evidence and the identification of best practices.

Social acceptance of this technology and of the new paradigm proposed for essential transport is a key factor to consider. Although it may be perceived as a social benefit, its initial implementation may encounter resistance from certain groups due to concerns related to safety and the privacy of individuals and property. However, it is expected that the deployment of UAS operations across the territory will initially take place in rural, mountainous or low-density areas with dispersed populations. In this sense, the implementation of a drone transport service such as that proposed in this study can be understood as a measure of territorial cohesion and an improvement in public services.

In line with the points outlined above, the use of drones in the healthcare sector in Catalonia has the potential to become a national and European benchmark, provided that it is supported by public policies aligned with technological, digital and sustainable development objectives, helping stakeholders to turn the vision outlined in this study into reality.

7.

Conclusions

The analysis of the feasibility of deploying healthcare logistics with drones, based on healthcare, territorial, logistical, operational risk and coordination criteria, has made it possible to establish that:

- The territorial structure of the Catalan healthcare system means that drone technology provides particular added value in rural areas, areas with difficult connectivity, or those with long healthcare distances.
- The operational risk analysed (GRC, CTR and hospital environments) makes it possible to identify a set of areas and centres that are potentially viable for regular operations in the short and medium term.
- The logistical comparison shows that drones offer clear advantages in terms of time and efficiency on long routes, secondary roads or routes with complex terrain, whereas in urban corridors and motorways, ground vehicles may retain a partial advantage, and a hybrid transport model combining drones and ground vehicles could be adopted.

- The three candidate areas illustrated in this report constitute suitable scenarios for pilot projects, both due to their operational feasibility and their healthcare relevance.
- The progressive use of drones in the healthcare sector in Catalonia is feasible and aligned with healthcare mobility challenges, provided that it is deployed gradually, in a coordinated manner and following strict safety protocols.

In summary, ten strategic areas have been identified, with 15 hospitals where it is considered feasible to deploy logistics routes for biological samples, pharmaceuticals and small medical equipment in the short and medium term.

8.

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9.

Annexes

ANNEX I: Categories of drone operations – Implementing Regulation (EU) 2019/947

Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 defines the rules and procedures applicable to the use of unmanned aircraft in Europe. The objective of this regulation is to provide minimum requirements to ensure the safety of UAS operations so that they can operate within the same airspace as manned aircraft.

The current European regulation applies to any unmanned aircraft, regardless of its mass and intended use (professional, recreational, experimental or specialised), and includes model aircraft used in aeromodelling. It also includes autonomous operations (without the possibility of pilot intervention) and, depending on the operational category, allows aerial transport with UAS and swarm operations.

To ensure operational safety, Implementing Regulation (EU) 2019/947 establishes three categories of operation: open, specific and certified. This classification is defined according to the level of risk of UAS operations, which is largely determined by the weight and dimensions of the aircraft: de l'aeronau:

- **Open category:** low operational risk. The open category has three subcategories with specific requirements:
 - * A1: flights over people are allowed, but not over crowds
 - * A2: flights close to people are allowed
 - * A3: flights far from people
- **Specific category:** medium operational risk, including operations such as:
 - * Flights beyond visual line of sight (BVLOS)
 - * Flights with drones with a maximum take-off mass (MTOM) of more than 25 kg
 - * Flights above 120 metres above ground level
 - * Operations in which material is dropped
 - * Operations with drones in an urban environment with an MTOM greater than 4 kg or without a class identification label
- **Certified category:** high-risk operations, such as drone flights carrying passengers. The safety standards in this category are broadly equivalent to those of manned aviation

ANNEX II: Interactive map layers

● Geographical political layers:

- * Catalonia layer: https://raw.githubusercontent.com/codeforgermany/click_that_hood/main/public/data/spain-communities.geojson
- * Healthcare organisation layers: <https://github.com/gloriamacia/regions-sanitaries-catalunya/tree/main>
- * Administrative layers: Geographic Information System (GIS) of the Generalitat de Catalunya. <https://sig.gencat.cat/iframeVisorACT/?language=ca&mode=full>

● Healthcare layers:

- * Layers with the locations of healthcare centres:
 - The addresses of all healthcare centres in the interactive map were obtained through the Catalan Health Service centre search tool (<https://catsalut.gencat.cat/ca/centres-sanitaris/cercador/>).
 - The coordinates and metadata of all locations were extracted by the Fundació TIC Salut i Social from the aforementioned repository. These data were converted into GeoJSON format compatible with the interactive map.

● Layers for drone risk analysis:

- * ARC layer:
 - Layer developed by the Fundació TIC Salut i Social based on the information available at https://ec.europa.eu/assets/estat/E/E4/gisco/website/census_2021_grid_map/index.html.
- * GRC layer:
 - Layer processed and filtered by the Fundació TIC Salut i Social based on the European GRC map. (https://ec.europa.eu/assets/estat/E/E4/gisco/website/census_2021_grid_map/index.html.)
- * Layer with sectors with population density > 5,000 inhabitants/km²
- * Layer processed by the Fundació TIC Salut i Social based on the GRC layer.

● Infrastructure layers:

- * Layer with the locations of heliports of the Emergency Medical Service (restricted access, SEM).
- * Layers with other infrastructures extracted from the GIS of the Generalitat de Catalunya. (<https://sig.gencat.cat/iframeVisorACT/?language=ca&mode=full>)

- **Territorial layers:**

- * All layers in the territorial section were extracted from the GIS of the Generalitat de Catalunya. (<https://sig.gencat.cat/iframeVisorACT/?language=ca&mode=full>)

- **Security network layers:**

- * Layer with police stations of the Mossos d'Esquadra:

- The addresses of all Mossos d'Esquadra police stations were obtained through the Generalitat de Catalunya address and telephone directory, specifically from the Department of Interior and Public Security a (https://www.policia.es/es/dependencias_localizador_accesible_provincias.php).
 - The coordinates and metadata of all locations have been extracted by the TIC Salut i Social Foundation from the aforementioned repository. This data has been converted into GeoJSON format, compatible with the interactive map.

- * Layer with Local Police stations:

- The addresses of all Local Police stations were obtained through the Generalitat de Catalunya's address and telephone directory, specifically from the Department of Interior and Public Security https://web.guardiacivil.es/es/colaboracion/atencionciudadano_1/directorio-de-telefonos-y-direcciones/
 - The coordinates and metadata of all locations were extracted by the TIC Salut i Social Foundation from the aforementioned repository. This data has been converted into GeoJSON format, compatible with the interactive map.

- * Layer with National Police stations:

- The addresses of all National Police stations were obtained through the "Dependencias Policiales por Provincia" search tool (https://www.policia.es/es/dependencias_localizador_accesible_provincias.php).
 - The coordinates and metadata of all locations were extracted by the TIC Salut i Social Foundation from the aforementioned repository. This data has been converted into GeoJSON format, compatible with the interactive map.

- * Layer with Guardia Civil stations:

- The addresses of all Guardia Civil stations were obtained through the "Directorio de Teléfonos y direcciones de las unidades de la Guardia Civil" search tool (https://web.guardiacivil.es/es/colaboracion/atencionciudadano_1/directorio-de-telefonos-y-direcciones/).
 - The coordinates and metadata of all locations were extracted by the TIC Salut i Social Foundation from the aforementioned repository. This data has been converted into GeoJSON format, compatible with the interactive map.

- **Density layers:**

- All density layers were developed by the TIC Salut i Social Foundation based on the previously mentioned data.



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