Structures and Rules in Capacity Constrained (urban) Environments

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DACUS

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Abstract

Human activities and infrastructures should generate a need in drone operations. These activities and infrastructures are clearly numerous in the cities and their surroundings. Peculiarities of urban environment, as much on the ground as in the air, and the communication, navigation and surveillance performances of the networks and the drones themselves will impact the way drone traffic will be managed.

Constraints of European, National and local regulations, often influenced by citizens opinions, imposed to operators, drone operations and drone itself will also differentiate the urban environment from the other.

These characteristics must be taken into consideration to define models of urban airspace and demand and capacity balancing measures that would be included in the demand and capacity balancing process.

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1 Executive Summary

All kind of drone operations will occur in urban environment, from photography to building inspection, goods delivery, passengers transportation and more. These operations will have different constraints related to the urban environment.

On the ground, population density, movement of the citizens during the day from residential to working areas, human activities, buildings and infrastructures will generate demand in drone operations but also influence the way drone operations are conducted and the traffic is managed.

In the air, the airspace structure, often characterized by a controlled Traffic Region due to the vicinity of an airport, will require a specific airspace organization with U-space, at least coordination with Air Traffic Control. Manned aircraft operations (e.g. medical, media, police helicopters) not specifically engendered by the airport activities will necessitate coordination/organization too.
Other structures, such as no drone zones over prison, hospital, school, or structures dedicated to drone flights such as corridors will have an impact on the traffic organisation.

Whether drones fly manually or autonomously, high performances of the communication, navigation and surveillance systems will be mandatory, provided the complexity of the urban environment and the number of operations that should occur.
Again, urban environment is challenging these systems. Some issues are already known (e.g. multipath effect, incapacity to detect a drone behind a building with radar currently in place).

Finally, current regulation, which is not exhaustive (e.g. the certified category operations remains to be developed), developed by EASA frames drone operations, but specific national even local regulations (especially those influenced by citizens) may facilitate or add complexity to drone operations.

Provided the above, it is clear that urban environment is complex, and the review of current U-space implementations does not show a strong implication in the development of urban operation, for the moment. The movement should accelerate in the coming years.
That's the reason why, without a clear view of how will be the drone operation in urban environment, at least three different airspace structures and rules models need to be proposed as a basis for the demand and capacity balancing process.

2 Introduction

2.1 Purpose of the document

This document aims to provide the reader with information which currently characterize ground, airspace, CNS and regulatory environments and linked to drone operations in urban areas.

Those characterizations will allow to propose a set of DCB measures in each domain based on the identified potential flexibilities that could benefit to the DCB process.

Additionally, they will allow defining the set of air rules and structures that should be implemented in urban environments to comply with the safety, environment and citizen’s acceptability requirements in urban areas.

2.2 Scope

This document focuses on the urban environment characterization in the domains of ground, airspace, CNS and regulations in order to depict the drone operational environment above populated areas as it is foreseen when a U-space demand and capacity balancing process will be useful.

2.3 Intended readership

Provided the content of the document, the first leadership should be the partners of the DACUS project to feed the DCB process.

Nevertheless, it could be of special interest for all the different authorities in charge of establishing the future regulation for drone operations in urban environment by providing them with a global picture of this environment.

For the same reason, it may concern people in charge of drone operations development or people who will have to deal with drone operations: U-space service providers, local authorities at the level of city or region, operators, Air navigation Service Provider, just to name a few.

2.4 Background

2.5 Structure of the document

The document is divided into four different sections:

The section 3 describes the ground environment in urban areas, taking into consideration aspects such as the population density, movement of the population during the day or the social impact of drone operations.
It also provides a picture of the airspace around and above urban areas. Are considered all the different kinds of operation which will occur in urban environment, whether they are manned or unmanned, the different current ATM and future U-space that may structure the urban airspace.

This section ends with an overview of the Communication, Navigation and Surveillance (CNS) performances in urban environment, at least at the state of current knowledge.
Sections 3 includes three subsections each containing a set of identified flexibilities and a set of DCB measures for each of them. Each characterization is also followed by an assessment of the impact on drone operations and on demand and capacity.

Section 4 depicts the regulatory framework as it is known today for manned and unmanned operations over urbanized areas.
This section also provides the results of the several consultations performed through surveys (results are detailed in appendix A and B) and bilateral meetings alongside citizens, European cities' authorities, National safety agencies or representatives of France, Germany and Spain and the European Aeronautical Safety Agency.
Given that the different regulations are still in progress, what this section provides seems to be some tendencies, feelings of what the regulations may looks like.

Section 5 is the results of bilateral meetings with Spanish, German and Italian Air Navigation Service Providers (ANSP), as well as personal involvement of the writer in the French U-space program.
The section describes how the four National ANSP see their national U-space and their involvement.
In addition, the document shows the roadmap for each country (Spain, Germany, Italy and France) of U-space services implementation.

The sixth section aims to propose three different models of airspace structures and related rules, one with low level drone operations constraints, one with middle constraints and the last one with a high level of constraints.

Finally, appendix C proposes a realistic view of city authority involvement in U-space from Toulouse Metropole.

2.6 Glossary of terms

Term	Definition	Source of the definition
Complexity	The number of simultaneous or near- simultaneous interactions of trajectories in a given volume of airspace. Note: This complexity definition refers to ATM context. For automation, complexity is relevant only in terms of calculation effort, not the ability to solve a given set of problems. Beyond a certain level of complexity, humans can no longer oversee all the consequences of the interactions and automation	SESAR Integrated Dictionary[1]

Founding Members

	support is required if traffic is to be handled safely and efficiently. See also Density.	
Density	In the ATM context, density refers to the number of simultaneous or near- simultaneous trajectories present in a given airspace volume. Note: High densities require specific procedures to ensure that the required capacity to handle traffic can be provided. See also Complexity	SESAR Integrated Dictionary[1]
Demand and Capacity Balancing (airspace)	The ability to evaluate traffic flows and adjust airspace resources to allow airspace users to meet the needs of their operating schedules.	EATMA V12[2] (ATM Capability)
Separation Provision (airspace)	The ability to separate aircraft when airborne in line with the separation minima defined in the airspace design (incl. aircraft separation from incompatible airspace activity, weather hazard zones, and terrain-based obstacles).	EATMA V12[2] (ATM Capability)
Service	A contractual provision of something (a non-physical object), by one, for the use of one or more others. Note: Services involve interactions between providers and consumers, which may be performed in a digital form (data exchanges) or through voice communication or written processes and procedures.	SESAR Integrated Dictionary[1]
Structural index (of Traffic Complexity Score)	The structural index originates from horizontal, vertical, and speed interactions and is computed as the sum of the three indicators. • Horizontal interactions index. A measure of the complexity of the flow structure based on the potential interactions between aircraft on different headings. The indicator is defined as the ratio of the duration of horizontal interactions to the total duration of all interactions. • Vertical interactions index. A measure of the complexity arising from aircraft in vertical evolution based on the potential interactions between climbing, cruising and descending aircraft. The indicator is defined as the ratio of the duration of vertical interactions to the total duration of all interactions.	Performance Review Unit  

	• Speed interactions indicator. A measure of the complexity arising from the aircraft mix based on the potential interactions between aircraft of different speeds. The indicator is defined as the ratio of the duration of speed interactions to the total duration of all interactions.	
Traffic Complexity Score	The Complexity Score is the product of two components: Traffic density and Structural index.	Performance Review Unit
Traffic density	The traffic density is expressed in Adjusted density which measures the (uneven) distribution of traffic throughout the airspace (i.e. taking into account the relative concentration).	Performance Review Unit

Table 1: Glossary of terms

2.7 List of Acronyms and abbreviations

Acronym	Definition
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
AESA	Agencia Estatal de Seguridad Aérea (Spanish NAA)
AFIS	Aerodrome Flight Information Service
AGL	Above Ground Level
AMC	Acceptable Means of Compliance
AMSL	Above Medium Sea Level
AMULED	Air Mobility Urban - Large Experimentation Demonstrations
ANSP	Air Navigation Service Provider
ARC	Air Risk Class
ATC	Air Traffic Control
ATS	Air Traffic Services
ATM	Air Traffic Management
ATSP	Air Traffic Service Provider
ATZ	Air Traffic Zone

BRLOS	Beyond Radio Line Of Sight
BVLOS	Beyond Visual Line Of Sight
C2 link	Command & Control link
CBD	Central Business Districts
CFR	Code of Federal Regulations
CIS	Common Information Service
CISP	Common Information Service Provider
CNS	Communication Navigation and Surveillance
CONOPS	Concept of Operations
CORUS	Concept of Operation for EuRopean UTM Systems
CTR	Controlled Traffic Region
DAA	Detect And Avoid
DACUS	Demand And Capacity Optimisation in U-space
DCB	Demand and Capacity Balancing
DFS	Deutsche Flugsicherung GmbH
DSNA	Direction des Services de la Navigation Aérienne (french ANSP)
EASA	European Aviation Safety Agency
EU	European Union
EATMA	European ATM Architecture
FAA	Federal Aviation Administration
FAR	Federal Aviation Rules
FIS	Flight Information Service
FPV	First Person View
Ft	Feet
GM	Guidance Material
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRC	Ground Risk Class
GSM LTE 5G	Global System for Mobile Long Term Evolution 5G
HEMS	Helicopter Emergency Medical Services
ICAO	International Civil Aviation Organization

IFR	Instrument Flight Rules
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
KJ	Kilo Joules
LAANC	Low Altitude Authorization and Notification Capability
Lb	Libra
LBA	Luftfahrt-Bundesamt
LUC	Light UAS operator Certificate
Maas	Mobility As A Service
MTOM	Maximum Take-Off Mass
NASA	National Air and Space Administration
NM	Network Manager
NOTAM	NOtice To AirMen
NPRM	Notice of proposed rule-making
OSO	Operational Safety Objectives
PAV	Personal Air Vehicle
RLOS	Radio Line Of Sight
RP	Remote Pilot
RPAS	Remotely Piloted Aircraft System
RPS	Remote Pilot Station
RTK	Real-time kinematic
SAIL	Specific Assurance and Integrity Levels
SERA	Standardised European Rules of the Air
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SORA	Specific Operations Risk Assessment
STS	STandard Scenario
SUMP - UAM	Sustainable Urban Mobility Plan/Policy – Urban Air Mobility
TMPR	Tactical Mitigation Performance Requirement
TOLA	Take-off and Landing Areas
U1, U2, U3, U4	U-space service level
UAM	Urban Air Mobility

UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
USSP	U-space Service Provider
UTM	UAS Traffic Management
V2V	Vehicle to Vehicle
VFR	Visual Flight Rules
VLL	Very Low Level
VLOS	Visual Line Of Sight
VMC	Visual Meteorological Conditions
VO	Visual Observer
WG	Working Group

Table 2: List of acronyms and abbreviations

3 Urban environment characterization

This chapter provides a system-wide description of the urban environments affecting drone operations directly. Firstly, the environment related to the ground is characterized. A typology of urban areas and definition of population density are included here. Then, the complexity of the airspace structures over urban regions is addressed. Consequently, the impact of urban infrastructures and weather factors on drone performances are discussed. From this considerations, technical drone performances are derived. In each section, operational measured related to a future Demand and Capacity Balancing process are identified based on the flexibility that the afore mentioned environments could allow.

3.1 Grounds characterization

This section examines highly relevant ground environment elements that can pose a constraint to the execution of drone mission in urban regions. Additionally, the long term expected drone operations impact over urban areas is discussed based on a use case analysis. Since the population acceptance on drone operations is crucial for the widespread of drone operations, assumptions are identified. These could serve for the design of future operational scenario.

3.1.1 Types of urbanized areas (e.g. industrial, commercial, home) and associated stakeholders

In the following, a general classification of type of urban regions and characterization through the **population distribution** is provided.

In general, four different morphological types can be distinguished: **monocentric, dispersed, linear and polycentric** urban regions [3]:

- Monocentric urban region: Regions with monocentric urban structures can be found in France, Spain, Portugal and countries in the northern and eastern parts of Europe, where cities are distributed over relatively wide areas.
- Dispersed urban region: Dispersed urban patterns are formed by scattered or sprawling cities, towns and suburbs with relatively low densities. Examples can be found in parts of Belgium, in northern Italy and in the south of Poland
- Linear urban region: Regions with linear forms of agglomeration have emerged along some of Europe's coastlines, for instance in Portugal, in the southern parts of Spain and France, and in the east of Italy. Linear urban regions are also present in mountain valleys in Switzerland and Austria
- Polycentric urban region: In polycentric urban regions, multiple cities lie in close proximity to one another. These kinds of regions can be found in the Netherlands, the western part of Germany and the southern half of the United Kingdom

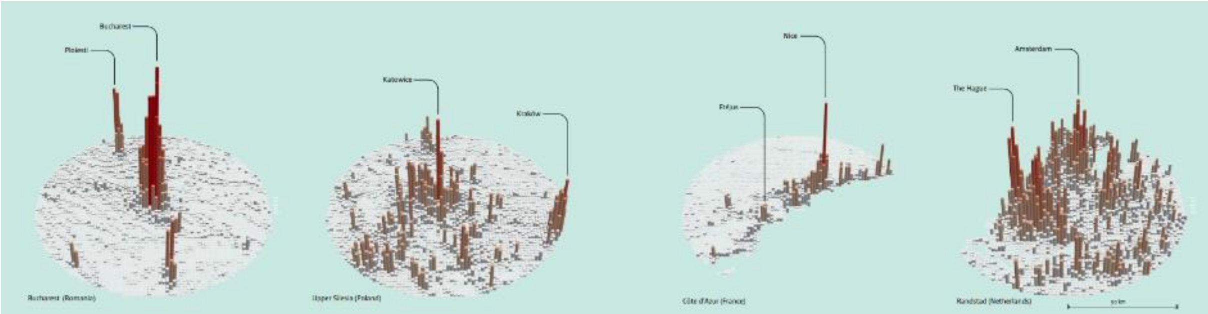


Figure 1 Different types of urban regions [3]

A region can further be classified through the **land cover**. The CORINE Land Cover inventory differentiates between 44 classes, both in rural and urban regions[2] . An excerpt of classes to be found primarily in urban regions is the following:

- Urban fabric (*Urban areas with dominant residential use or inner-city areas with central business district and residential use*)
- Industrial, commercial, public, military, private and transport units (*At least 30% of the ground is covered by artificial surfaces ((surfaces where landscape has been changed by or is under influence of human construction activities). More than 50% of those artificial surfaces are occupied by buildings and / or artificial structures with non-residential use, i.e. industrial, commercial or transport related uses are dominant*)
- Road and rail networks and associated land
- Port areas
- Airports
- Construction sites
- Green urban areas (*areas for predominantly recreational use such as gardens, zoos, parks, castle parks and cemeteries*)
- Sport and leisure facilities
- Water bodies

Based on this classification, the corresponding land use and relevant stakeholders of these areas have been identified:

[2] https://land.copernicus.eu/pan-european/corine-land-cover

Urban area	Land use and relevant stakeholders
Urban fabric	• Downtown areas • City centres • Central Business Districts (CBD), as long as there is partial residential use
Industrial, commercial, public, military, private and transport units	• Industrial units: Sites of industrial activities, Production sites, Energy plants • Commercial units: Surfaces purely occupied by commercial activities, High-rise office buildings • Public, military and private units: Surfaces purely occupied by general government, public or private administrations (Schools, Hospitals, Places of worship, Administration buildings, Military areas)
Road and rail networks and associated land	• Areas enclosed by roads or railways • Railway facilities including stations, cargo stations and service areas
Port areas	• Administrative area of inland harbours and seaports • Infrastructure of port areas, including quays, dockyards, transport and storage areas
Airports	• Administrative area of airports, mostly fenced • Included are all airport installations: runways and buildings
Construction sites	• Spaces under construction or development
Green urban areas	• Not included are private gardens within housing areas area.
Sport and leisure facilities	• All sports and leisure facilities including associated land, whether public or commercially managed
Water bodies	• Sea • Lakes • Rivers, including channelled rivers • Canals

Table 3 Urban areas and related use of land

3.1.2 Long term expected drone operations impact on ground

For characterizing the impact that long term expected drone operations could have on the ground, a use case analysis is performed. From the operational characteristics general impact factors are derived.

Use Case Analysis

Use cases involving drone missions that take place over different urban areas and analysis of the routes:

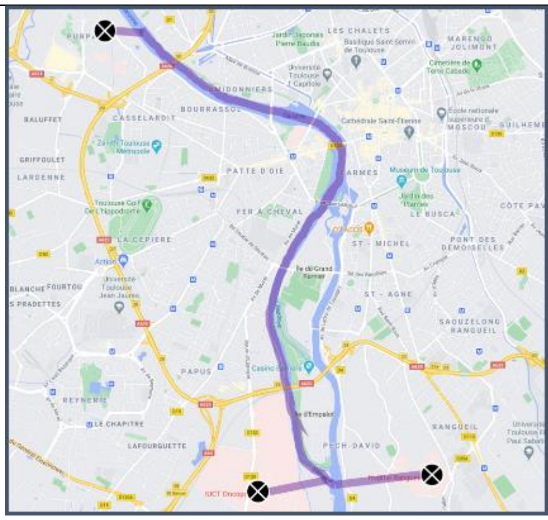
<table>
<tr><td>Mission Type:
Transport</td><td>Use Case:
Medical and blood transportation network</td><td rowspan="2">
Not conclusive route, only based on take-off and landing areas</td></tr>
<tr><td colspan="2">Operational characteristics:
Take-off and landing areas: 3 hospitals
Route: majority over river
Operating hours: mostly in the daytime</td></tr>
<tr><td colspan="3">Identified urban areas and characteristics:
River (Water bodies)
Hospitals (Industrial, commercial, public, military, private and transport units) – populated areas during operating hours
Roads (Road and rail networks and associated land) – populated areas during operating hours
Parks (Green urban areas) – populated areas during operating hours</td></tr>
</table>

Table 4 Example of use case over Toulouse

Impact on the ground

The use case presented previously showcases the impact of a single operation on urban areas. Even though it is a very high-level description of the operation, it encompasses various urban areas with different characteristics and involving several stakeholders (see Table 3). Previous research has identified further representative operations that could take place in future urban environments, so as the relevant operational characteristics that have an impact on the ground characterization. Table 5 summarizes these findings. The future market sectors are derived from a recent survey (UAS OPS survey from AW Drones project).

Mission Types	Surveillance	Inspection	Transport
Relevant future application fields	• ES (Fire, Police, EMS, Coastguard) • Construction • Private Security Services • Aerial Mapping / Photography	• Infrastructure • Insurance • Real Estate • Media and Entertainment	• Medical • e-Commerce (retail, food) • Industrial/ Corporate
Relevant operational characteristics impacting the ground	• Deployment of drones over private property (*Private Security Services, Construction*) • Recurrent flight operations with noise/visual impact to third parties (*Photography*) • On-site flight operations inside a foreseeable containment area (*Aerial Mapping*)	• On-site flight operations close to structures (*Infrastructure*) • Recurrent flight operations with noise/visual impact to third parties (*Insurance, Real Estate*) • Close range operations inside a foreseeable containment area (*Media and Entertainment*)	• flight operations over mixed urban areas (*Medical, e-Commerce*) • On-site flight operations close to structures (Industrial/ Corporate)
Associated urban areas (most relevant identified)	• Industrial, commercial, public, private • Construction sites	• Industrial, commercial, public, private • Urban fabric	• Urban fabric • Industrial, commercial, public, private • Road and rail networks • Green urban areas • Water bodies

Table 5 Summary of operational characteristics per mission type and application field

From this analysis, general impact factors of the representative operation on the ground have been identified:

- **Take-off and Landing Areas (TOLAs):** The TOLAs give the geographical references of the operations on the ground. For some transportation mission types, like direct point-to-point transport missions, the locations only consist of two areas. For other transport / delivery concepts, such as last-mile delivery, there could be several TOLAs, for instance one distribution hub and multiple receiving vessels. Linking the TOLAs with an inspection or surveillance mission type can provide already a good reference on the deployment areas for these operations, as in many applications the deployment area is confined to the on-site private area or a certain containment area.

- **Nominal mission route planning:** The required mission route determines the urban areas to be overflown. Depending on restrictions (for instance the prohibition to fly over traffic roads or public areas) or risk considerations, the route could be planned accordingly and avoid specific type of areas. However, for some applications, like transport of goods, it might be unfeasible to avoid certain areas at all costs. As it has been shown in the use case, a nominal route for a long range operation could the defined over rivers, which represent an area with no population.

- **Contingency / Emergency management:** Especially for long range operations, it is important to consider feasible alternative routes and TOLAs, which could cover different urban areas as the originally intended for the nominal operation. Various operational concepts propose the use of open areas or even building's rooftops as suitable emergency landing areas. According to the classification of the land use provided in the previous section, the urban areas that could be considered as suitable contingency / emergency landing areas are from the urban fabric, commercial, public and green urban areas types. The other types (private, road and rail network) might represent a great challenge in terms of suitable infrastructure, regulative aspects and risk considerations. One important aspect to consider here is the availability of this ground infrastructure during the operational timeframes.

- **Operational timeframes:** The operating hours can have a large influence on the final route definition and for instance, the impacted ground areas. In certain timeframes of the day, some areas might have a large population density. Thus, it might be suitable to avoid these areas. The other way around, routes could be designed particularly over non-congested areas. For some applications, like emergency response, this might not be feasible at all. In general, it is important to link the urban area type with the population in the temporal scale in order to assess the feasibility of the operation during the schedule timeframes.

3.1.3 Population density and movement in and across the different areas

The **population density** can be defined as the number of people living per unit of an area (e.g. per square kilometre) or for instance as the number of people relative to the space occupied by them [4]. Especially relevant for the integration of the population density in quantitative risk assessment concepts, it is mandatory to define the size of a grid cell (minimum grid resolution). A minimum population density of each grid element can be also used as a criteria to identify **populated areas** for instance.

Also important to characterize is the **population distribution** in urban regions. In general, multiple indicators can be used for estimating the population distribution:

- Census counts
- Geospatial input or ancillary datasets:
  - Land cover;
  - Roads;
  - Slope;
  - High resolution imagery analysis.

The possible occurrence of the population during a certain timeframe (e.g. a day) can be derived from the spatial data and socioeconomic and cultural understanding of an area. One approach to model the population distribution is to calculate a "likelihood" coefficient for a given cell and to apply the coefficients to the census counts, which are employed as control totals for appropriate areas. The total population for that area is then allocated to each cell proportionally to the calculated population coefficient. The resultant population count is an average day/night population count[3]. The output of this type of model is the number of people per cell or the population density distributed over a certain area.

3.1.4 Assumptions on population acceptance of risks and drone operation impact

Assumptions on the population acceptance of risks are divided based on either their impact on the mission planning or the ground infrastructure. These assumptions will serve both for the identification of DCB measures (through flexibility analysis) and for the design of operational scenarios.

Assumptions impacting the mission planning

- The type of urban region can be a decisive assumption as it is relevant factor in the planning of future operations. Especially those which involve the establishment of defined route networks. Given the morphology of the urban regions, different network systems could result, or certain "preferred" routes or corridors could emerge. For instance, within a linear urban region, large corridors on water bodies could be preferred by drone operators due to low risk level that they represent for the third parties.
- Rejection or opposition of the citizens to operations over certain urban areas and therefore the need for adaptation of mission route as original intended. Considering the urban area

[3] https://landscan.ornl.gov/documentation

classification provided, the impact of the social acceptance could be directly linked to certain urban area types where the citizens could have a direct influence, such as public and green urban areas.

- Minimum altitude over certain areas with dense population to minimize noise impact / to reduce noise levels / to reduce visual impact. For the assessment of these impacts a survey has be carried out in the scope of this project and the results are presented in Chapter 4.
- Limited operating hours over certain areas. In the previous sections it has been discussed about the characterization of the urban areas with regard to the population density inside them at certain timeframes. Urban area types like commercial, public, green urban areas and sport / leisure facilities could be considered for the deployment of drone operations at only at specific timeframes.

Assumptions impacting the ground infrastructure

- Ground infrastructure could be established at "optimal" locations with good accessibility and connectivity with other transportations systems. *(Particularly relevant for PAVs)*
- Certain urban areas will restrict the establishment of ground infrastructure based on community acceptance. *(Particularly relevant for PAVs)*
- The consideration of contingency / emergency landing areas has been discussed in the previous considerations. However, from the urban area classification it is evident that some type of areas (, public, green urban areas and sport / leisure facilities) are more suitable than others (private, road and rail networks, airports and surrounded areas) for establishing safe alternative landing areas.

3.1.5 Impact on drone operations in urban environments and in demand & capacity balancing

The previous sections from 3.1.1 to 3.1.4 have described the ground environment and drone operations impact on it.
This section will identify the influence of the ground environment on the drone operation and how it could change the demand and the capacity.

3.1.5.1 Types of urbanized areas based on the morphological type

The different types of urbanized areas could be divided into two groups, linear and polycentric in the first group, monocentric and dispersed in the second.

In the first group, urban areas look like a single volume where all types of urban operations will occur in a seamless way from one city to another. For instance a continuous corridor may cross the whole urban area. The same corridor would have to consider in its structure the other types of operations that would be performed outside urban environment when linking two cities of the second group.

Moreover, extended urban areas of the first group may attract several USPs and as a consequence increase the complexity to plan an operation without good coordination.

All drone operations are concerned, but more specifically those that will cover long distance above the urban area or those which will depend on several USPs.

3.1.5.1.1 Impact on demand and capacity

Demand
The complexity should impact the demand negatively as well as the proximity of several potential customers might allow operators to optimize one operation by satisfying two different customers
Capacity
The possibility to organize the flows in seamless manner may increase the capacity

3.1.5.2 Types of urban areas based on land use

For practical reasons (e.g., road network and access for truck) most of the time and often nowadays for societal considerations(e.g., visual and noise pollution), zones of activities in an urban area are separated from residential areas.
In terms of drone operations, it means that during working time, activities areas will generate a lot of drone operations, in particular those directly related to the activities themselves (e.g., professional deliveries). We could also assume that this period would accommodate drone operations in residential areas while most of the people are in the working places (e.g., surveillance, delivery in gardens or dedicated hubs, buildings inspections). Nevertheless, this assumption may be easily deleted if the teleworking keeps developing.
After all, we can admit that drone operations will decrease out of the working time in the activities areas, thus including night and week-end.

3.1.5.2.1 Impact on capacity and demand

Demand
Hence, demand may be the same along the day in residential areas, with a significant reduction after dinner time, whereas the demand may collapse after working time over activities areas (e.g., port, airport, commercial and industrial areas)
Capacity
The capacity will depend on several factors such as the separation minima between drones and drones and drones and manned aircraft, or between drones and obstacles, as well as how low and high they are authorized to fly, amongst other factors. As we can find high obstacles both in residential and working places, the capacity would be more influenced by the proximity of manned aircraft and the possibility to fly as low as possible.

As a consequence, we can assume that the capacity will be reduced near airport and manned aircraft take-off and landing zones (e.g., hospital), and where a minimum flight level has been set to avoid noise pollution for instance. This level could be activated after dinner time in residential areas for example.

3.1.6 Identification of DCB measures related to the ground environment

The methodology used to identify the possible DCB measures that could be set with regard to the ground environment characterization was first to define what seems to be flexible in that field and in what manner. Flexibilities found were grouped in domains which were inspired by the flexibilities themselves.
From these flexibilities have been derived DCB measures.

3.1.6.1 Brainstorming on flexibilities

Domains	Comments/ideas
Societal impact	• "Time of operation" • "limit hours of operations over certain areas" "Speed limitation to reduce noise impact" • "Allow more operations during "rush hours" as the noise traffic will mask the noise made by UAS"
Ground risk	• "Restrictions to fly over specific areas such as schools (possible at week-ends for instance)" • "Only temporarily used infrastructure which normally would not be allowed to be overflown" • "Restricting people to walk in areas with a high number of drone operations" • "Being able to detect the ground risk in real time" • "Flexibility on routes by caring on ground environment (e.g. avoid to fly over building, citizens)" • "Dynamically controlling the minimum height in response to the ground risk"
Traffic management	• "Flexibility to order drone operations to fly/remain over unpopulated urban areas (e.g. empty stadium)" • "Is a recognized distribution center subject to any capacity constraint or is it their responsibility to manage independently?"
Ground structures	• "If take-off and landing zones exist for air taxi service, do these become restricted for other traffic" • "Locations of areas where you can arrive or depart or not" • "Number of drone ports"

Table 6 Flexibilities related to ground environment

3.1.6.2 DCB measures derived from flexibilities

From the flexibilities identified in the previous table, a set of DCB measures is proposed and listed in the following table with three characterizations:

- The timeframe (in which phase of the flight preparation this measure could be applied)
- The area of applicability (does it concern some parts of the airspace or the whole volume)
- The impact on capacity and/or the demand

Each DCB measure is linked to one domain of flexibility.

DCB measures	Timeframe	Area of applicability	Impact on capacity and/or demand
Limit time of operations	Strategic	Over certain areas	Should reduce capacity and demand
Increase or decrease take-off/landing areas	Strategic	Over the whole urban area	Should increase or reduce capacity and demand
Limit the volume of airspace dedicated to one operator responsibility	Strategic	Could be a whole urban area, but probably more localized	Should increase capacity and demand
Limit types of operations linked to ground risk (e.g. movement of population)	Strategic, pre-tactical and tactical	Everywhere the ground risk may change	Should reduce the demand

Table 7 DCB measures related to ground environment flexibilities

3.2 Airspaces characterization

The airspace characterization in this section examines the low-level airspace environment over urban areas. This section also provides an analysis of existing and emerging UTM implementation concepts. Through the analysis of these concepts, invariant airspace design elements are derived that can serve as a catalogue of airspace structures and rules in the design of future urban environments.

3.2.1 Existing ATM airspace structures above/around urban areas and related U-space services requirements

The most common ATM airspace structures are those related to airports/heliports infrastructures:

- **CTR (Control Zone)[5]:** usually defined around airports to protect the air traffic operating to and from an airport, any drone flight taking place in such volume of airspace requires coordination with Air Traffic Service Provider (ATSP) designated for that airspace. Additionally these kind of drone flights require authorisation of the National Competent Authority.

- **ATZ (Aerodrome Traffic Zone)[6]:** intended to protect the aerodrome traffic, i.e. the traffic on the manoeuvring area and the traffic in the immediate vicinity of an aerodrome, the precise form and dimensions of the ATZ may vary from country to country. This airspace is usually included in CTR, but it may be either in uncontrolled airspace (in which case e.g. aerodrome flight information service (AFIS) is offered). In any case, coordination with ATSP and Airport Operator, as well as National Competent Authority authorisation are required in order to fly a drone in this volume of airspace.

Currently, drone operations taking place in these airspaces (CTR and/or ATZ) are on most occasions segregated operations, which although may have an impact on ATC, do not entail direct interaction with ATC. However, many urban airspaces are typically highly affected by CTRs, and with the increasing demand of drone operations, integrated operations will be needed in order to increase capacity. In such scenario, collaborative interface with ATC, tactical de-confliction and dynamic capacity management U-space services might turn into mandatory services in order to ensure safety.

- **Class G airspace[5]:** in this airspace class, separation services are not provided and Flight Information Services (FIS) are provided under request, thus this airspace is considered "uncontrolled". VFR and IFR flights are allowed, as well as drones flights following national regulation.

- **No flight Zones:**

  - Prohibited area[6]: within which the flight of aircraft is prohibited, and which are used to protect governmental buildings and critic infrastructures.

  - Restricted area[6]: within which the flight of aircraft is restricted in accordance with specific conditions.

  - Danger area[6]: within which activities dangerous to the flight of aircraft may exist at specified times, usually related to military manoeuvres.

  Any operator willing to fly in these areas might require authorisation from the NSA and/or from the Competent Authority on charge of such area.

  In addition, according to EASA U-space Regulation [7], currently under development, it is stated that U-space airspace is designated by Member States, who have the power to decide how their airspace is designed, accessed, restricted, etc. Corus Project [8] proposes this U-space airspace is divided into three different types of volumes, which include the "UAS geographical zones" envisaged in current regulations [7] and are defined based on the different number of drone flights, the associated air and ground risks, security and social acceptance factors, and U-space services needed to enable a safe operation. These volumes differ in two ways: the services being offered and hence the types of operation, which are possible, and their access and entry requirements.

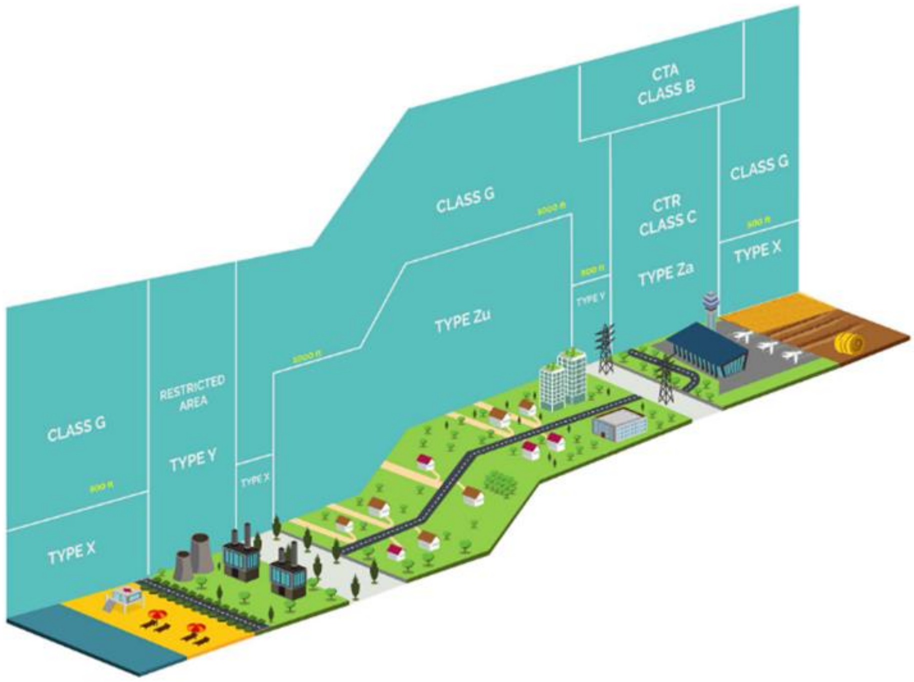


Figure 2 Overview of U-space volumes as defined by CORUS[8]

Three airspace volume types are identified and referred to as X, Y and Z:

- X Volumes: There are few basic requirements for accessing airspace this airspace volume, but thus few services are offered, in particular no conflict resolution service is offered. Main characteristics of X volumes are the following:
  - The pilot remains responsible for separation at all times
  - VLOS flight are easily possible, and other types of operations require significant attention to air risk mitigation

Hence, X volumes are expected in regions with both low demand for U-space services and low ground and air risk.

- Y Volumes: access to this volume requires an approved operation plan and specific technical requirements may need to be met. This volumes facilitate VLOS and BVLOS flight and main characteristics of Y volumes are the following:

- There are risk mitigations provided by U-space which are not available in X
- Strategic conflict resolution service is provided
- Tactical conflict resolution service is not provided, which will result in widely spaced aircraft
- Traffic Information service is provided, which requires all aircrafts to be tracked
- The Y airspace may have a minimum performance requirement for position reporting: in some areas, the reporting of start of flight and end of flight may be sufficient.

Y volumes are expected in areas where the ground or air risk determined by a SORA or otherwise (including regulation) are too great for an X volume, for example where there is significant air (drone) traffic or over a densely populated area.

- Z Volumes: allow higher density operations than Y, and hence are expected in areas where demand of traffic exceeds the capacity of Y, or there is particular risk. The following requirements are needed to access Z volumes:
  - An approved operation plan
  - The pilot continuously connected to U-space
  - Position report submission for the aircraft with enough performance to enable tracking

  In addition, Z airspaces may have specific technical requirements attached to them, which need to be met for the approval of the operation plan. Main characteristics of Z volumes are the following:
  - Tactical conflict resolution service is provided.
  - Facilitate BVLOS and automatic drone flight and also allow VLOS.
  - More risk mitigations provided than in Y or X.
  - Allows higher density operations than Y; residual risks from strategic separation can be reduced by tactical conflict resolution, hence the residual risk after strategic conflict resolution need not be as low as in Y.

3.2.2 Identification of existing manned operations in urban environment

A compendium of the following existing manned operations in urban environment is as follows:

- Police helicopters
- HEMS (Helicopter Emergency Medical Service) helicopters
- State helicopters
- Traffic Surveillance helicopters
- Private helicopters

Most of these flights are VFR, and in the near future will need to cohabitate with unmanned aviation. Thus, the use of systems to ensure conspicuity, for both manned and unmanned aircrafts, could become mandatory.

This would imply then, that bearing in mind the associated risks, congestion and the requirement for the mandatory provision of traffic information and tracking services, this would imply that those U-space airspaces in urban environments where manned operations may take place need to be categorised as Z Volumes, according to CORUS Project [8] U-space volumes. Zu in non-controlled U-space airspace and Za in controlled U-space airspace.

However, it should be also taken into account that police and state helicopters might be exempted of this due to privacy and security reasons. In addition, some of these operations, such as those from HEMS helicopters, cannot been planned in advance, and may require priority when a conflict occurs. This will imply that coordination mechanisms with military, law enforcement authorities and emergency services need to be defined and implemented, since these operations may impact on DCB process.

3.2.3 Assumptions on VLL and ground vertical boundaries in or above urban areas

CORUS Consortium [8] defines VLL as the airspace below that used by VFR, and according to SERA section 5005 “Visual Flight Rules” the minimum and maximum that may be flown by a VFR flight are the following:

- (d) Unless authorised by the competent authority in accordance with Regulation (EC) No 730/2006, VFR flights shall not be operated: (1) above FL 195;
- …
- (e) Authorisation for VFR flights to operate above FL 285 shall not be granted where a vertical separation minimum of 300 m (1 000 ft) is applied above FL 290.
- (f) Except when necessary for take-off or landing, or except by permission from the competent authority, a VFR flight shall not be flown:
- over the congested areas of cities, towns or settlements or over an open-air assembly of persons at a height less than 300 m (1 000 ft) above the highest obstacle within a radius of 600 m from the aircraft;
- elsewhere than as specified in (1), at a height less than 150 m (500 ft) above the ground or water, or 150 m (500 ft) above the highest obstacle within a radius of 150 m (500 ft) from the aircraft.

However, the vertical boundaries in or above urban areas should not be defined taking into account only the above mentioned requirements, since there are many manned operations in urban areas allowed below this level – as mentioned in previous section 3.2.2 of this document -, which must be allowed to carry out their activities without putting safety at risk.

Bearing this in mind, for the purpose of this project the proposed assumptions on VLL will be the following: in urban areas, the vertical limit of the VLL will be 120 m over the highest building inside a radius of 600 m around the flying drone. It should therefore defined a volume in urban areas in a digital way to take into account different vertical boundaries. One example could be a grid similar to FAA's LAANC where there are different vertical boundaries depending on the position. Outside urban areas, the vertical limit of VLL will be 120m AGL.

3.2.4 Analysis of existing and emerging UTM airspace structure concepts

Future urban airspaces in VLL will likely not only accommodate a large number of drone flights in close proximity with each other, but will also face the demand for a wide range of missions with contrasting operational characteristics in terms of range, flight levels and autonomy level. These considerations put high requirements for the development and implementation of an exhaustive eco-system that can handle heterogeneous urban drone traffic safely and efficiently. In recent years, several concepts have emerged and all of them address relevant challenges in the design of urban airspaces, such as structuring the traffic or supporting the flights in emergency or conflicting situations.

In line with the U-space development objectives, the CORUS project has proposed dedicated volumes dividing the VLL airspace that especially support the deployment of operations as envisaged by the European regulation (under the Open, Specific, Certified categories) [9]. Fundamentally, each volume type is characterized by the set of U-space services being offered and by the type of operations which are possible.

Furthermore, the Metropolis project has studied a number of airspace structure concepts with an increasing level of structure and traffic organisation [10]. This is only possible by defining separation requirements and applying routing strategies. Similarly, NASA has examined and simulated a concept of sectionalisation of the airspace in urban areas [11] . The UAM Concept of Operations of the FAA also proposes specific an airspace structure (corridors) for operations of UAM aircraft based on operational performance and participation requirements [12].

Based on these existing approaches, fundamental **airspace design elements** have been identified and it is necessary to address them at least to some extent. In the following, each element will be explained in detail and the existing concept solutions will be presented.

General Airspace Structure

Structure and non-physical constraints determine the most obvious design elements that indicate how drones can navigate. Depending on the structure complexity, different design concepts can be divided as the following:

- Non-structured: In this structure design, all drones can use the airspace freely, without any non-physical constraints. This design allows a direct routing in drone operations. However, in order to ensure safety, a prescribed airborne separation assurance algorithm needs to be in place for the drones to avoid each other while flying their optimal route. In regard with the representative operations introduced in the last section (operations of surveillance, inspection and transport type), this structure concept might seem suitable for all operations types as it offers maximum flexibility to accommodate the operational characteristics of the three types.

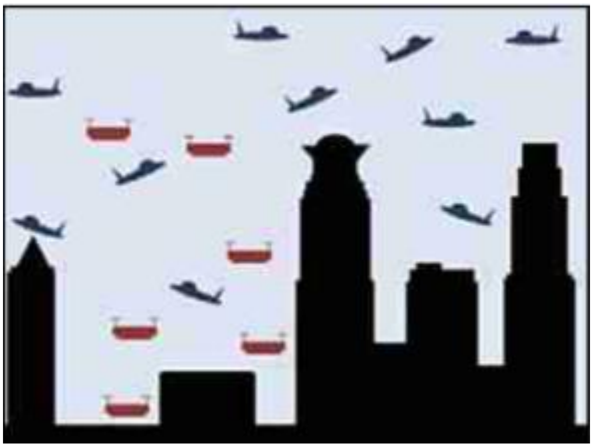


Figure 3: Non-structure design (METROPOLIS Consortium 2014)

- Layers: In this design, the airspace is segmented into layers of certain vertical dimensions. In each layer specific traffic mechanisms can be applied, such as traffic flows limited in the heading range [13] or to assign layers only for de-confliction purposes [14]. This structure design also provides the possibility to accommodate drones equipped with different performance characteristics. Here it might be necessary to implement dedicated tubes or cones above take-off and landing sites for the vehicles to enter the layers.

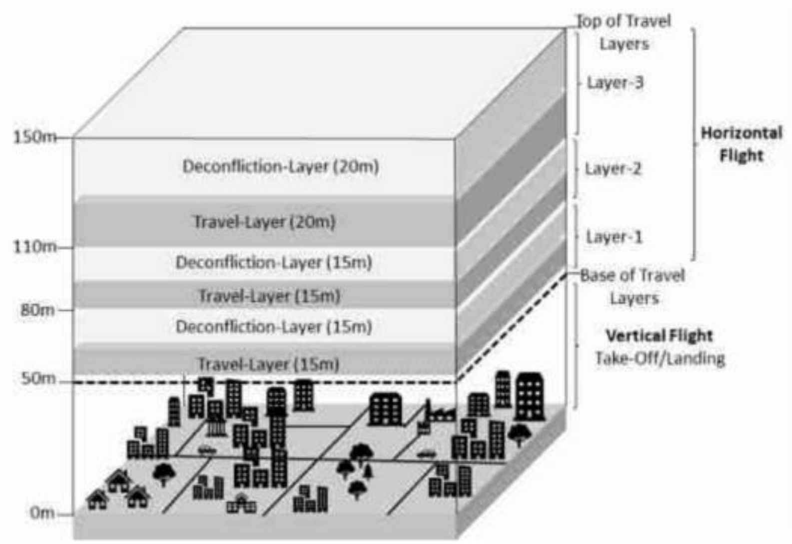


Figure 4: Layer design [14]

- Zones: This is a design that is based on the principle of airspace today, which means different zones for different types of drones, speed ranges as well as global directions [13]. This makes possible the application of different rules and traffic management strategies depending on urban areas and vehicle types. For instance, here it is possible to assign higher levels of urban airspace to PAVs.

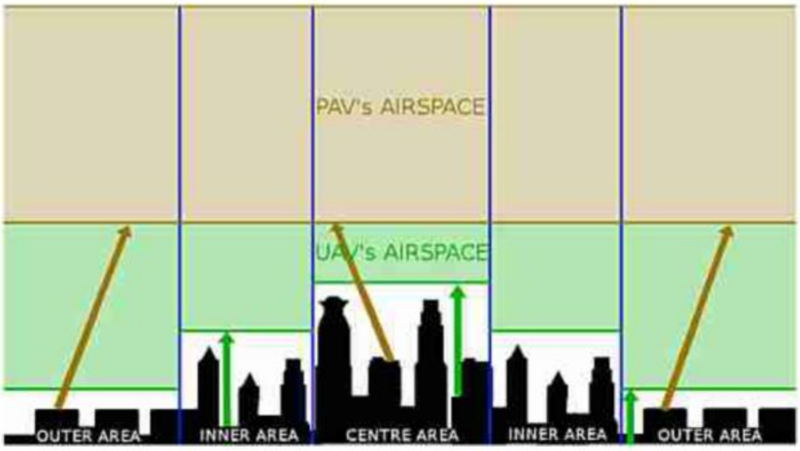


Figure 5: . Zones design [13]

- Corridors/Tubes: This design offers the maximum structuring of airspace, where 3-dimensional corridors provide a fixed route structure in the air. Different directions, speeds and vehicle types could use different corridors ensuring safety by separating potentially conflict traffic. As separation is ensured based on time, this approach requires the highest level of traffic coordination.

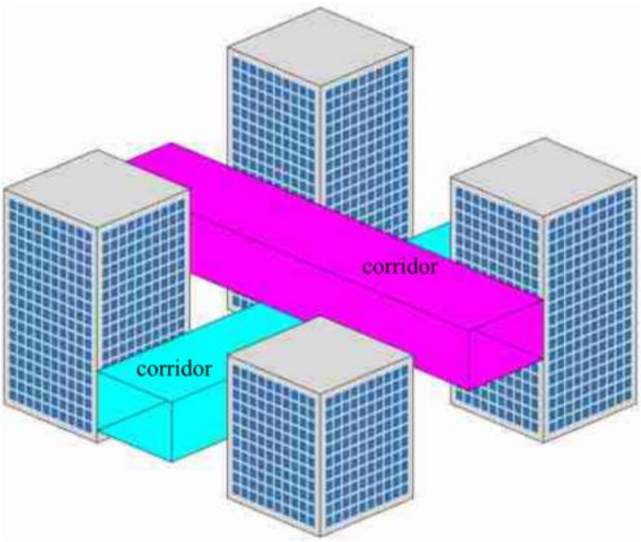


Figure 6: Corridors design

Routing Strategies

After defining an airspace structure in VLL, it is necessary to clarify what are the routing strategies that the structure design can support or that make sense to implement within. Here, the concepts for routing strategies are treated separately from the airspace structure concepts as one routing strategy concept could be implemented in different airspace structures or could be an extension of a general approach for structuring the airspace. To what extent the final implementation will look depends on several factors such as the traffic coordination that can be provided or the drone performance required to comply with the route strategy. Imposing a route principle with a high level of complexity might pose a challenge for several business models, but at the same time the level of traffic organization and operational safety could increase significantly. The following general strategies have been identified:

- Free/direct routing

In this routing principle, no restrictions on the path of the drone are generally imposed. This means that the drones are allowed to fly long distances directly from their starting point to their destination, and both flight speed and altitude can be adjusted or optimized based on mission requirements. However, simulations have shown that applying this principle without any coordination mechanism can lead to a high number of conflicts as traffic volumes increase [15].

- Routes with grid-like structure

A radically different approach is the definition of a grid-like structure consisting of a network of nodes and edges. Nodes are locations where drones are allowed to change directions, while edges are the lines connecting the nodes. A natural separation results on the edges, but it is certainly required to further coordinate the flights to ensure that two drones do not occupy the nodes and edges at the same time. Research on this structure has revealed that efficient pathfinding is required for generating a path between two point in airspace that is direct as possible and that avoids No-Fly Zones [14]. It is also evident that this approach is most suitable for multi-copter drone types which are able to fly over nodes and edges using a standard waypoint planning.

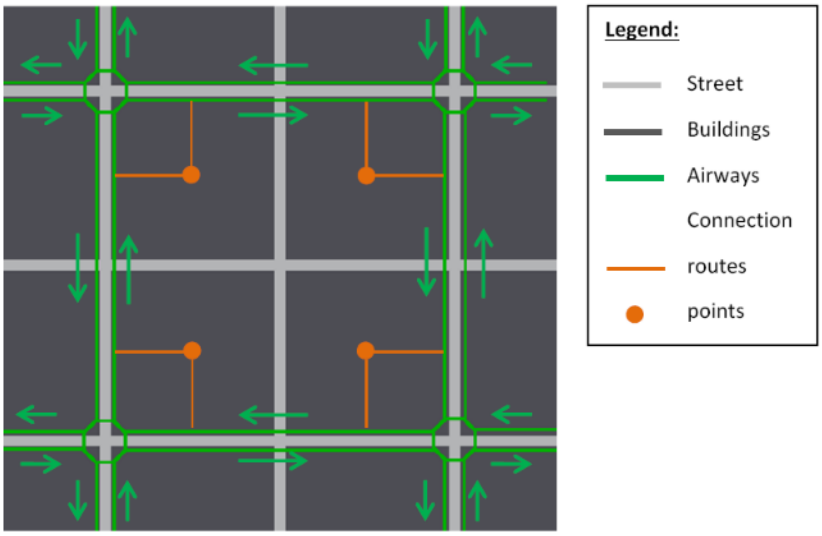


Figure 7: Topology of a bi-directional airway structure based on nodes and edges with a defined direction [13]

- Routes following a global direction

The principle of this approach is to limit horizontal flights within the allowed heading range. The rationale for following this strategy is to reduce the probability of conflicts in conjunction with a limitation of the relative velocities between the drones, while still allowing a certain degree of freedom in the routing [10]. Implementing this strategy and covering all possible directions would require to add more levels vertically (see Figure 8). Climbing and descending between these vertical levels require special attention in order to ensure safety.

Figure 8: Implementation of the routing strategy with a prescribed heading range (45° in this case) using multiple altitude bands [10]

- Routes within a corridor/tube

The main characteristic of the routing inside a corridor or tube is that separation is based on time, which requires a high level of management. Time delays also pose a challenge as they need to be coordinated quickly. Studies like [14] have tested temporal safety margins to cope with these situations.

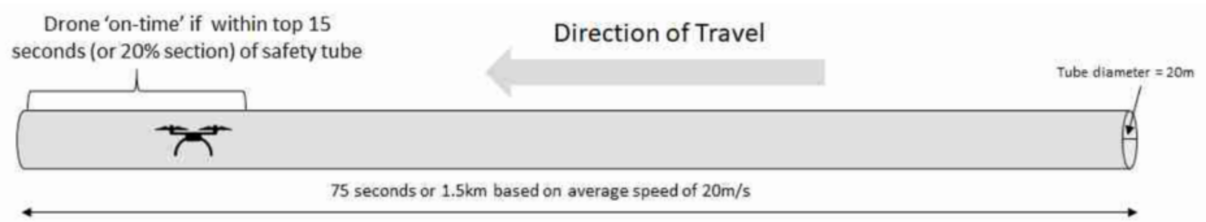


Figure 9: Drone flying inside a tube and indicating a correct position if within a temporal margin (McCarthy et al. 2020).

Air Traffic Limits

- Height

Introducing concepts for the sectorization of the airspace implies that drone operations are mostly restricted in the vertical dimension (see Layers and Zones structure concepts and altitude bands for routing strategy). This might not pose a challenge for missions with a cruise phase to a destination area. But for other mission types with variable altitude profiles (e.g. aerial mapping) this could be an important limitation.

- Speed limits

The European Regulation already sets maximum speeds in flight levels for the different classes of drones (EASA 2020). Moreover, speed limits could be introduced in combination with routing strategies in order to organize traffic flows.

- Restricted Zones

No-Fly zones specify locations or zones on the ground, together with a vertical flight layer, which are not accessible for drone operations. These normally comprise permanent physical structures of critical character, like government buildings, but also elevated temporary structures like cranes at construction sites. Over certain areas it might be possible to travel the airspace above but only after receiving a permission beforehand and only for a certain timeframe. Reasons for restricting these areas could include safety, security, privacy and nuisance concerns. Depending on the character of the area, it might be reasonable to activate the restriction only at certain timeframes (public events with dense population). On the contrary, zones with little or no vulnerable infrastructure and very low levels of human activity on the ground could be reserved in order to free-up space during an unforeseen external event or in the case of an emergency. The figure below depicts these three types of zones described:

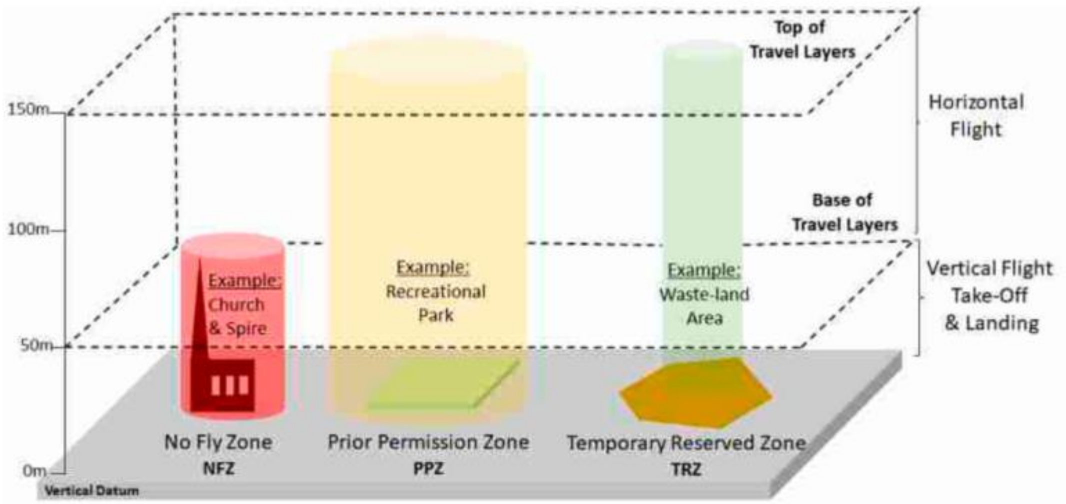


Figure 10: Schematic detailing of No-Fly Zone, Prior Permission Zone and Temporary Reserved Zone (McCarthy et al. 2020).

Operation and Traffic Management

Although it is not entirely clear who will be responsible for managing dense drone traffic in urban areas, there are invariant services and capabilities that need to be in place for a safe and efficient organization of the traffic. Especially when establishing airspace structures with advanced route strategies, it is paramount to organize the traffic streams. For instance, when organizing traffic flows along single dimensional travel lanes (as in the tubes/corridors airspace structure concept), a spacing between the travelling drones must be given and the higher the level of safety required the higher the spacing has to be. But at the same time, a maximum capacity of the flow could be achieved if the drones travel at a regulated speed [16]. Regulating these traffic parameters could further be used to adapt the traffic flows based on high traffic demands. This, without compromising the level of safety established evidently. For these mechanisms to be implemented, there are two key services that need to be in place for efficient management:

- Tracking (position reporting): position reporting is an essential U-space service and the automatic submission will allow continuous tracking of the drones as they travel through dense airspaces. Depending on the level of information provided (3D position, speed, uncertainty) it will be possible to use advanced measures to regulate the traffic.
- Emergency management: the timely communication of foreseen delays and emerging emergency cases during the flight is necessary for the traffic management services to react accordingly. Even if the routes have been defined in a manner that no conflicts should appear, it is important to contemplate operational and technical failures that can force the drone to deviate from its nominal route. For these situations, a define emergency management plan must be in place.

Conflict Management and Separation

The importance of defining spacing between the drones has been previously mentioned, but ensuring conflict avoidance requires a wide set of functions and mechanisms in place. These will be based on the given airspace structures and the resulting traffic streams. From a general perspective, well-structured conflict management is comprised of three layers, namely strategic conflict management; separation provision and collision avoidance [17]. The U-space framework envisages a set of services to cope with the management of these layers, but there are still open questions on how exactly the services will provide the necessary functions. The implementation of conflict resolution strategies will also require the cooperation of drone systems.

Operational Procedures

- Departure and landing procedures

As soon as demand increases and several drones seek to enter urban airspaces it will be necessary to establish departure and landing procedures, as these zones could become the most dense volumes in the very low-level airspace. A high demand in congested zones can generate delays, but there could be measures for compensating waiting times on the ground and in flight. Possible options for adjustments in flight are speed adjustments; route stretching; holding patters, or hovering [13].

- Contingency procedures

Operational contingency procedures can serve to minimize the impact of emerging hazards for handling abnormal situations in general. Weather is a highly relevant factor influencing drone traffic (especially affecting small and medium size drones) which require resolution strategies having the lowest impact on the overall traffic. Such strategies could also be applied to other unforeseen events, like temporary restricted areas. Lastly, the strategies dealing with uncooperative traffic require special attention as the dynamic of rogue aircraft could require advanced capabilities to reduce the risk of an air collision.

3.2.5 Long term expected drone operations impact on airspace structure

The following section comprises a number of identified drone mission and operation characteristics that could have a considerable impact on airspace usage as soon as the different business models irrupt in urban regions:

- Route network based on logistic systems: Delivering goods on a large scale could require advance route networks that enable efficient flights. A consequence of these could be the establishment of preferred routes (with a low risk for instance) that multiple operators would prefer to use.
- Priority of certain mission types (e.g. emergency): It is still not clear yet how the priority of certain mission types will be managed. But it is valid to say that some type of operations will require a special kind of priority to operate and they could impact the regular traffic considerably.
- Operations with increased level of autonomy: To overcome regulative and operational barriers, innovative technologies are being integrated on drone systems and are currently being tested (e.g. D&A). In turn, these technologies could be applied for advanced conflict management strategies and open the door to the implementation of complex airspace structures.
- Organisation and coordination between UAV and PAVs: As soon as a large traffic of UAVs and PAVs emerges in urban environments, the separation and coordination between these both system classes will become very critical. There is already research addressing the safe traffic management of these systems [13].

3.2.6 Impact on drone operations in urban environments and on demand & capacity balancing

3.2.6.1 Existing ATM airspace structures in urban environment

Proximity of airport and urban environment, and no flight zones (section 3.2.1) inside the city such as volumes above prisons or around manned aircraft take-off and landing zones (e.g., hospital with heliport) will have to be considered by U-space and integrated in U-space airspace structures.
Using these different ATM airspace structures will require close coordination with the authorities responsible for these areas.
If the urban environment is not inside a controlled airspace and few manned aircraft are authorised to fly in, it is required that all operations, whether manned or unmanned are known, at least to create a geo-fence around the manned aircraft or to manage the traffic.
Even if a city is in a class G airspace, according to the ICAO annex 2[6] , the minimum height at which a manned aircraft could fly over a city is above the VLL boundary. Hence there is no conflict with transiting manned aircraft.

3.2.6.1.1 Impact on demand and capacity

Demand
The existence of an ATM airspace structure should decrease the demand in that area because of specific requirements on drone equipment and/or on the remote pilot qualification(s) or because of specific procedures(e.g., authorisation request).
Capacity
The capacity of the entire airspace (including the ATM airspace structures) for drone operations should also be reduced, as a lot of drones will have to avoid ATM structures on one hand, and probably higher separation minima between drone and manned aircraft will be applied inside the ATM structure for those drones allowed to fly in, on the other hand.

3.2.6.2 Existing and emerging UTM airspace structure concepts

Section 3.2.4 shows the different UTM airspace structures that could be put in place for drone operations in an urban environment. Drones could fly how they want or be obliged to use routes and/or dedicated flight height/level, all depending on their route, their missions, etc.…

3.2.6.2.1 Impact on demand and capacity

Demand
An airspace where a total freedom is given to drone operators is probably willing to increase the demand, if it is not restricted by constraining requirements on drone equipment for instance. A more structured airspace, with routes, corridors, dedicated level/height or directional/bi-directional routes could reduce the demand because some operations could be hard or even impossible to achieve because of a limited corridors network for instance(e.g., no corridor to the final destination or the corridor increase the distance to be covered by the drone which is not compatible with some drones' autonomy).
Capacity
Because of separations and several conflict points in the airspace, a non structured volume would reduce the capacity and DCB measures triggered often. Airspace with routes, corridors and flights organized with levels/heights increases the capacity. Flows are easier to managed(e.g., some routes could be dedicated to slow drones, other to drones with high speed), structures dedicated to drones only allow to avoid higher separation with manned aircraft…

3.2.7 Identification of DCB measures related to the airspace characterization

The methodology used to identify the possible DCB measures that could be set with regard to the airspace environment characterization was first to define what seems to be flexible in that field and in what manner. Flexibilities found were grouped in domains which were inspired by the flexibilities themselves.
From these flexibilities have been derived DCB measures

3.2.7.1 Brainstorming on flexibilities

Domains	Comments
Impact of VLL height	• “Increase the top of VLL when the traffic demand reaches a predefined level. Manned aircraft should above” • “VLL vertical boundaries depends on national regulations. Some countries may increase the VLL height over urban areas”
Speed limitations	• “Speed controlled zones” • “Temporary speed limitations” • “speed limit zones where separation is a function of speed – slower aircraft can be closer together”
Airspace sectorization	• “sectorize the airspace vertically based on autonomy/routing strategy” (e.g. “flight levels” are assigned depending on routes) • “Keep reserved/buffer airspace” to increase capacity when necessary. • “create U-space areas in controlled airspace where the ATCO is no more responsible”. USP could be responsible. • “Create corridors with activation/deactivation possibility” • “Areas of movement: levels, tubes, flows, regions, geo-fencing” • “impose traffic patterns per layer”
Flexible use of airspace	• “Temporarily authorize forbidden area”
Other	• “Weather limitation on airspace use” • “close the airspace for important event”

Table 8 Flexibilities related to airspace environment

3.2.7.2 DCB measures derived from flexibilities

DCB measures	Timeframe	Area of applicability	Impact on capacity and/or demand
Increase VLL vertical boundary	Strategic	Over certain areas where the traffic requires it	Increase capacity

Define speed in certain portion of airspace	Strategic and pre-tactical	Specific areas only may be concerned	Could increase or reduce capacity and demand (the level needs to be discussed)
Drone operations dedicated airspace structures	Strategic and pre-tactical	The whole urban area	Could increase capacity and demand (see METROPOLIS project for capacity improvements)

Table 9 DCB measures related to airspace environment flexibilities

3.3 CNS performance in urban environment

Communication, navigation and surveillance may be impacted by urban infrastructures.
Drone operations only transiting above populated areas high enough may not be impacted by the urban environment, at least probably not at the same level than those having to fly close to the buildings, for inspection or delivery for instance.

This section will discuss the Communication, navigation and surveillance systems that may be impacted by urban infrastructures in particular and may pose a threat to the execution of safe operations [18].

As some of the causes of such impacts are still under investigations, some parts of the text below must be considered as assumptions.

3.3.1 Communications

The following communication systems may be affected by urban infrastructures :

- between the drone and the RPS (Remote Pilot Station): Command and Control link (C2 link), voice link through the drone with other party (e.g. ATC), telemetry data coming from the drone for monitoring and RP (Remote Pilot) situational awareness purposes, but also image coming from the camera for RP situational awareness or as a goal of the operation (e.g. surveillance, inspection).

- or between the drone and the U-space service provider: whether the drone flies manually or autonomously, it would impact the safety by preventing (or simply by delaying them) the drone and/or the RP to receive crucial information such as geo-awareness information or tactical de-confliction measures.

- or between drones themselves or with any other aircraft: any anti-collision or situational awareness systems based on collaboration between aircraft will see their efficiency decrease.

- between the remote pilot/operator and any third party such as the Air Traffic Control for instance. Even if the RP can reach the ATC through his smartphone (if such a communication is possible and only in case of emergency) instead of through the link on the drone, he may encounter difficulties in urban environment.

The coverage of the urban areas with antennas dedicated to each type of communication in order to increase the quality, the capacity or the range could be a solution; this would also be a major factor that can hinder the deployment of BVLOS operation in urban areas; but several issues have to be mentioned:

- technical problem with the potential electromagnetic interferences caused by all the transceivers on the systems around

- societal problem: in urban environment, citizens are close to the antennas and the impact on health of the electromagnetic waves, whether it is justified or not, may prevent any installation of additional antennas or communication network

In previous research, key communication performance parameters have been identified. Especially the following parameters could be considerably impacted in urban environments with a high variety of communication networks:

- Continuity, availability, integrity;
- Coverage;
- Data delivery time / latency;
- Bandwidth;
- Data transfer security

The communication performances could also evolved in real time during the day, subject to some potential issues identified above. A U-space service in charge of monitoring communication disturbances and associated to the degradation of the communication infrastructure (The Communication Infrastructure Monitoring service will be in charge of monitoring the communication performances and reporting alerts to U-space in real-time) may introduce flexibilities in the way the reduction or the increase of the capacity is managed.

3.3.2 Navigation

Navigation, which is mainly via the GNSS for drones, is specifically impacted in urban environment by the multipath effects[4]. This means that the drone may not know exactly where it is and if it sends its

4 https://www.researchgate.net/publication/289284263_Multipath_effects_in_RTK_GPS_and_a_case_study

position to the other aircraft and/or to a U-space service provider for tracking, surveillance, monitoring or tactical de-confliction for instance, it could be useless if the recipient does not receive anything, even dangerous if what is received is erroneous.

Other threats to GNSS are performance degradation due to RF interference and blocked radio line-to-sight of GNSS constellations. Jamming or spoofing could suddenly degrade navigation accuracy. Other navigation means may then be required to avoid contingency procedures.

Similarly as with communication systems, accuracy, integrity and availability performance parameters are crucial in the impact analysis of navigation systems. But also the continuity of service needs to be ensured, especially for the phases of the operation where the drone heavily relies of the integrated navigation systems.

Any issue negatively impacting drone navigation performances will also impact the capacity of the volume of airspace concerned. The demand might be impacted too if additional on-board equipment and/or drone capacity are required.

A U-space service monitoring these performances may, as for the communication, positively influenced the capacity and demand but closely managing the variations in real time.

This service could be based on a specific network of ground based antennas which positions are known for sure and verifying that positions are the same via the GNSS.

Real time testimony from drone pilots could also inform the other users, via the same service.

3.3.3 Surveillance

The conspicuity of drones is probably one of the most important things with regard to manned aviation, also to unmanned aviation if we consider drones which will carry passengers or sensitive freight (e.g. blood, defibrillator) and for security reasons. Drones are expected to be collaborative, meaning that they will broadcast their position in order to be seen. We have seen in the section dealing with the communication that an “information” sent by a drone may not reach a receiver, or with delay.

That is the reason why it could be useful to detect a drone, at least to know the position of a drone whose system which broadcast its position is broken or to detect drone used for malicious purpose.

Nowadays such detection systems exist, and they are able to detect drones between buildings or hidden by buildings, but their cost is quite high and they are more expected to be used to “protect “airport from unexpected drone flight. Given the size of many drones on the market, we could add that such detection systems would not be useful only in urban environment but everywhere a drone is supposed to fly.

3.3.4 Weather constraints

Inherently, airborne vehicles are sensitive to atmospheric conditions. The predominant effects concern flight stability, energy consumption and battery lifetime as well as structural stress and disturbance of internal systems. Another consequence that should not be neglected in the context of UAS is the effect on the overall CNS performance. In the following section we will discuss several weather phenomena, which need to be observed especially in relation to CNS in urban environments.

3.3.4.1 Glares

Glares affect a visual surveillance and navigation of aircrafts in VLOS as well as BVLOS operations. Operators and observers on the ground are impeded to follow or recognise the own UAV as well as the air traffic situation. It appears in clear skies due to blinding sunlight. Furthermore, visual aiding systems like cameras on airborne systems can be hindered to record clear pictures when facing direct sunlight.

3.3.4.2 Temperature

All technical systems on-board and on-ground are to be operated under conditions as specified by the manufactures, typically between -20 and +50 °C. If this range cannot be guaranteed a system failure of CNS modules is possible and will therefore impede its performance.

3.3.4.3 Humidity

Much as temperature, humidity can cause failures in electronic systems. If water enters the operating systems it "can cause electronic short circuit which results in erroneous behaviour, loss of functionality or high amounts of heat output that lead to a fire." (Ranquist 2017)

3.3.4.4 Clouds, Fog and Haze

As in most regulations (FAA, EASA) VLOS operations are not allowed under foggy or cloudy conditions. But for surveillance and navigation in BVLOS operations it can become relevant as it is hindering a clear First-Person View (FPV) via cameras and has the potential to dissolve the functionality of detect-and-avoid systems that are based on optical sensors. A good example for this situation are LIDAR sensors which cannot penetrate fog effectively or conventional camera lenses that steam up.

3.3.4.5 Rain

Precipitation strongest effect on UAVs concern the control and aero dynamicity. Apart from that, it can have the same effect on electronics as high levels of humidity if the affected system is not built for such conditions. Fortunately, GPS and GNSS systems are operating on normal parameters even in heavy rain events. Negative effects here are in a range of – 2 dB

3.3.4.6 Solar Storms

Flares and coronal mass ejections of the sun can heavily impact CNS performance, especially GPS and GNSS transmissions. As these signals need to pass through the ionosphere to be received it is essential that such events are observed and forecasted much like any other atmospheric condition that endangers the safe and efficient operation of UAVs.

3.4 Required drone performances in urban environment

Drone technology and performances for flight in cities will constantly improve in foreseeable future. Currently it is possible to safely fly in cities if the right processes are applied. The biggest issues are power, navigation and communication. Advances in sensor technology and CNS will make Urban canyons less of a threat.

3.4.1 Location accuracy (take-off / landing/delivery)

GPS has proven to provide acceptable accuracy while in flight above the cityscape in an urban environment, however to achieve accuracy within an acceptable safety envelope in an urban environment GPS alone will not be enough to handle landing / take-off and delivery.

Take-off is on many systems used as a reference or calibration point for the duration of the flight, location accuracy is therefore important at this stage. This can be achieved with set locations, RTK or other near field location systems (multiple new technologies are entering this space - 5G location services etc…).

The following is based on the experience of AHA in Iceland during its operations of delivery drones which started in August 2017.

During landing it can be quite critical to have very high accuracy. Even with ample space around the landing spot then space comes at a high cost in an urban environment and quickly economic constraints (relating to space) will start to put pressure on safety standards. The more accurate the location the less of a risk this will cause. Landing accuracy can be achieved with multiple technologies such as RTK, lasers / radar for height calibration and other near field location systems.

Most of the same points apply to the delivery part of the journey, if delivering via wire then height accuracy is of importance as well as accurate delivery location.

3.4.2 Redundant systems (motors / batteries / flight controller / communications)

A key component during flight in an urban environment will be the ability to handle failures gracefully. Therefore, we need to assume that any component can fail and that the aircraft can handle itself in a manner to reduce ground risk. Therefore, redundancies of all key components keeping the drone in control and in flight are required (Motors, controller, batteries). This allows for intervention in case of failures where a failsafe route can be executed (Return to home, safe landing spot or worst case end the flight in a risk-free location).

3.4.3 Emergency systems (parachute) (what about taxi drones)

In case of absolute failure where control is lost or redundant systems are not capable of keeping the drone in safe flight, execute an emergency procedure where all motor power is killed and a parachute deployed. This should be done in such a way that the drone causes minimal harm.

3.4.4 Battery safety buffer (flight returns at 30%)

Within the urban area all flight routes, procedures and systems should be aiming for the aircraft to return with a minimum of 30% batteries or 7 minutes of flight.

3.4.5 Weight / noise limit

Contrary to common belief, drones under 25 kg max take-off weight cause little noise interference in flight. A well-planned operation will ensure that take-off / landing spots are either enclosed in such a way to limit noise or on rooftops. 5 deliveries a week in a garden will cause less noise than the lawnmower for the same garden.

With larger drones above 25 kilograms and air taxis, noise is more likely to become an issue. This can however be mitigated by proper design of take-off and landing points. It is likely that emerging technologies will handle the noise issue in flight and after that focus will be on take-off and landing. Significant improvements have been seen in large scale battery powered aircraft over the recent years for example with KittyHawk Heaviside[5].

3.4.6 Risk analysis / emergency landing sites

Even if not part of drone performance it is important that the drone systems are suitable to perform actions outlined in risk analysis and to be able to reroute and fly to emergency landing sites or perform a risk mitigated crash landing.

3.4.7 Sense and avoid

Multiple approaches have been made to solve the sense and avoid problem. It is likely that in an urban area this will be a mix of on-drone sensors and a public collision avoidance real-time system (possibly based on rooftop radars and air traffic control data).

3.4.8 Building infrastructure (related to weather / GPS / Noise)

The ability to fly within building infrastructure becomes more important in an urban landscape. Buildings can cause turbulence, GPS and compass errors and generally cause multiple unintended side effects to the flight of an unmanned drone. This needs to be mitigated with on-board sensors and nearfield location systems.

3.4.9 Impact on drone operations in urban environments and on demand & capacity balancing

[5] https://kittyhawk.aero/blog-post/the-future-of-flight-can-be-energy-efficient/

3.4.9.1 CNS performances

Whether it is navigation, surveillance or communication, safety level of flights is linked to the performances of the CNS systems. Section 3.3.4 also adds some information on how weather constraints could degrade CNS performances of a system.
Investments in CNS infrastructures and drone equipment, in particular if the aim is to dispose of the most capable systems, with better performances against weather constraints, may significantly increase the cost of an operation.

3.4.9.1.1 Impact on demand and capacity

Demand
The constraints imposed to drone equipment to be allowed to fly in certain airspaces could reduce the demand.
Capacity
CNS performances will impact the capacity of the airspace. Better communications, more accurate navigation and improved surveillance capabilities should allow more drone flights in a volume.

3.5 Identification of DCB measures related to the CNS performance

For the methodology used, please refer to section 3.1.5.

3.5.1.1 Brainstorming on flexibilities

Domains	Comments/ideas
Drone equipment / drone performance	• "mandatory fit of cooperative detect and avoid in some high traffic density volume" • "Impose equipment on board in certain areas" • "performance/capability based restrictions" • "add redundant systems to cope with adverse CNS performance in certain areas" • "minimum navigational performance requirements in every airspace. Separation minima set in function of that minimum performance"
CNS structures and characteristics	• "Increase and/or improve communication network" • "Availability of ground telecommunication and charging infrastructures" • "increase signal strength, available bandwidth"
U-space services	• "Active monitoring, publication and even forecasting of phenomena that can influence navigational performance (e.g. micro-weather, electromagnetic interferences)"

	• “Due to capacity constraints, request to contract additional USSPs with higher fidelity of service provision or additional services”
Other	• “Impose autonomous fight in certain areas” • “Request for human in the loop to be able to react in contingency situations for operating in more complex airspace”

Table 10 Flexibilities related to CNS environment

3.5.1.2 DCB measures derived from flexibilities

DCB measures	Timeframe	Area of applicability	Impact on capacity and/or demand
Impose equipment requirements	Strategic, pre-tactical	Over certain areas where the traffic requires it	Capacity and demand
Subscribe new services or higher quality services	Strategic, pre-tactical	Specific areas only may be concerned	Capacity and demand

Table 11 DCB measures related to CNS environment flexibilities

3.6 DCB measures with no peculiar link with previous characterizations

In addition to the several possible DCB measures that have been identified in sections 3.1.5.2, 3.2.6.2 and 3.5.1.2, one measure can be linked to any of the characterizations developed previously: the fact to delay some operations.

4 Regulatory Framework

4.1 EASA regulation for drone operations in populated/urban environment (open, specific categories (SORA), certified)

4.1.1 Introduction

EASA and consequently European regulation has taken as input the work of The Joint Authorities for Rulemaking on Unmanned Systems (JARUS) which defined three different categories of operations based on the risk involved by the operation itself.

These three categories are known to EASA as Open, Specific and Certified.

Operations in the open category present the lower risk and should not require UAS that are subject to standard aeronautical compliance procedures, but should be conducted using the UAS classes that are defined in the annex of the Commission Delegated Regulation (EU) 2019/945[19] . These "Open" category operations are limited in various ways to constrain risk, for example VLOS only, take-off mass must to be less than 25kg, maximum height is 120m. Operations under the "Open" category will be of minimum relevance to the DACUS DCB concept, given the restrictions imposed on these vehicles.

The specific category covers other types of operations presenting a higher risk and for which a thorough risk assessment should be conducted to indicate which requirements are necessary to keep the operation safe. The Acceptable Means of Compliance (AMC) and Guidance Material (GM) [20] to Commission Implementing Regulation (EU) 2019/947[9] describes the use of the widely known risk assessment methodology is the Specific Operation Risk Assessment (SORA) [21], developed by JARUS. But other methodologies could be used (AMC1 1.2(a) of [20]). The specific category covers operations in VLOS and BVLOS and hence should be one of the most frequent categories of operation (with the certified) occurring in urban environment within the DACUS framework.

The remaining category, "certified" should, as a principle, be subject to rules on certification of the operator, and the licensing of remote pilots, in addition to the certification of the aircraft pursuant to a Regulation which is being established.

It is important to note that the European Aviation Safety Agency does not make distinction between professional and recreational usage of a drone.

4.1.2 General statements for drone operations in urban/populated areas

The execution act (UE) 2019/947 dated 24th of May of 2019 brings with articles (21) and (22) some important information for drone operation in urban and/or populated environment, provided that the conditions described below are usually met in that kind of areas.

(21) Some areas, such as hospitals, gatherings of people, installations and facilities like penal institutions or industrial plants, top-level and higher-level government authorities, nature conservation areas or certain items of transport infrastructure, can be particularly sensitive to some

or all types of UAS operations. This should be without prejudice to the possibility for Member States to lay down national rules to make subject to certain conditions the operations of unmanned aircraft for reasons falling outside the scope of this Regulation, including environmental protection, public security or protection of privacy and personal data in accordance with the Union law.

(22) Unmanned aircraft noise and emissions should be minimized as far as possible taking into account the operating conditions and various specific characteristics of individual Member States, such as the population density, where noise and emissions are of concern. In order to facilitate the societal acceptance of UAS operations, Regulation (EU) 2019/945, parts 13, 14 and 15 includes maximum level of noise for unmanned aircraft operated close to people in the 'open' category. In the 'specific' category there is a requirement for the operator to develop guidelines for its remote pilots so that all operations are flown in a manner that minimizes nuisances to people and animals.

4.1.3 Operations in the open category

Only operations where UA are flown in Visual Line Of Sight may be part of this category.

The Open category of operation is divided into three subcategories, all of which mandate VLOS operation, which concern five classes of drone (C0 to C4) which must meet various criteria laid out in Commission Delegated Regulation (EU) 2019/945 [22]

The table below provides some of the characteristics required for the drone and in which environment it could be used. Only those characteristics which could have an impact on the DCB process have been selected.

All the drones from the classes C0 to C2 could be flown in urban or populated environment.

<table>
<tr><th colspan="2">UAS</th><th colspan="3">Operation</th></tr>
<tr><th>Class</th><th>MTOM</th><th>Subcategory</th><th>Restrictions</th><th>Max height</th></tr>
<tr><td>Privately built</td><td rowspan="3"><250g</td><td rowspan="4">A1(can also fly in subcategory A3</td><td rowspan="3">•May fly over uninvolved people (should be avoided when possible) – no fly over assemblies of people

•Maximum speed: 19m/s</td><td rowspan="4">120m

+15m over obstacle taller than 105m (on request of responsible entity)</td></tr>
<tr><td>0</td></tr>
<tr><td>Legacy drones(art.20)</td></tr>
<tr><td>1</td><td>900g</td><td>•No expected fly over uninvolved people (if happens, should be reduced) – no fly over assemblies of people

•Maximum speed: 19m/s

•Maximum sound power level: 81dB</td></tr>
</table>

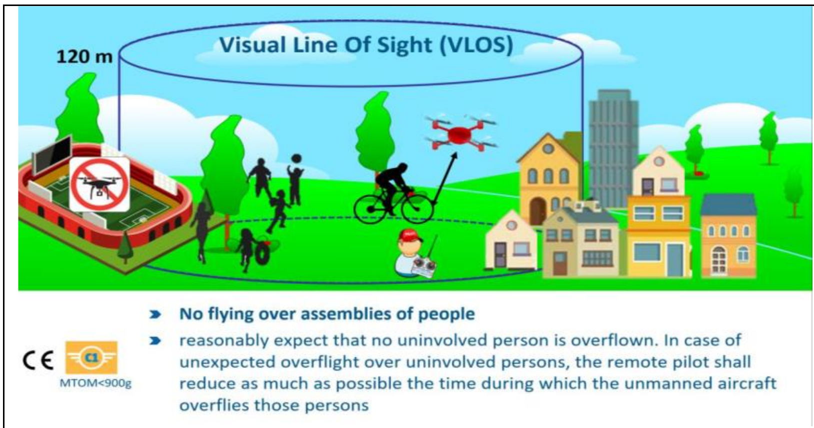
				
2	<4kg	A2(can also fly in subcategory A3)	•No fly over uninvolved people and 30m horizontal distance (5m with low speed function) •Maximum sound power level: 81+18,5 lg m/900 dB	
3 4 Privately built Legacy drone(art.20)	<25kg	A3	Fly away from people and outside urban area (from residential, commercial, industrial or recreational areas)- (150m)	

Table 12 Open category operations restrictions and requirements

4.1.4 Operations in the specific category

4.1.4.1 General information

This category of operation allows to fly drone in VLOS and BVLOS, which naturally includes most of the deliveries and surveillance operations, but also VLOS operations above populated areas which are forbidden in the open category of operation.

In order to fly in the specific category, an operator:

- Shall provide the competent authority with an operational risk assessment for the intended operation according to article 11 of (EU) 2019/947.
- Or shall provide a statement that the operation satisfies the operational requirement set out in point (1) of UAS. SPEC.020 of (EU)2019/947 and a standard scenario as defined in Appendix 1 to the Annex of (EU) 2019/947;

- Or holds a light UAS operator certificate (LUC) with the appropriate privileges. An LUC holder is granted the privilege to authorize its own operations.
- Shall provide the commitment of the UAS operator to comply with the relevant mitigation measures required for the safety of the operation, including the associated instructions for the operation, for the design of the unmanned aircraft and the competency of involved personnel.
- Unless an operator holds a Light UAS operator Certificate (LUC) authorizing him to fly the drone above, the maximum height for operation in the specific category is 120m above ground level.

4.1.4.2 Standard scenarios

Two standard scenarios have been currently defined and the following general provisions are common for both:

- Maximum 120m above the ground and 15m above an obstacle of 105m high with an horizontal distance of 50m.
- The operational volume shall not exceed 30m above the maximum height allowed.
- Dangerous goods are forbidden for transportation.

4.1.4.2.1 STS-01: VLOS over a controlled ground area in a populated environment, with the following key points:

For untethered aircraft:

- The Ground must be controlled.
- A contingency area of 10m beyond the flight geography area and a ground risk buffer up to 60m. The distance of the buffer is as important as the height of flight is high (details in (EU) 2019/947 appendix 1 UAS.STS-01.020 UAS operations in STS-01).
- A maximum speed of 5m/s.

For tethered aircraft:

- A radius equal to the tether length plus 5 m and centred on the point where the tether is fixed over the surface of the earth.

4.1.4.2.2 STS-02: BVLOS with Airspace Observers over a controlled ground area in a sparsely populated environment:

The controlled ground area includes:

- the flight geography area;
- the contingency, which its external limit(s) shall be located at least 10 m beyond the limit(s) of the flight geography area;
- a ground risk buffer covering a distance that is at least equal to the distance most likely to be travelled by the UA after activation of the means to terminate the flight specified by the UAS

manufacturer in manufacturer's instructions, considering the operational conditions within the limitations specified by the UAS manufacturer.

The operation must have the following requirement:

- The flight visibility must be at least 5km.
- Drone in VLOS at least during the launch and recovery, except for an emergency flight termination. Also, in VLOS during the flight or at a maximum distance of 1km without an observer and following a pre-programmed trajectory.
- With an observer (which distance is no more than 1km from the remote pilot), the distance could be 2km from the remote pilot, but at a maximum distance of 1km from the observer (there could be several).
- The UAS must be operated with an active system to prevent it from breaching the flight geography and be operated with active and updated direct remote identification system.

The standard scenarios introduce two new classes of UA whose characteristics which could impact the DCB process are listed in the table below:

Class	Scenario	Requirements
C5	STS-01	Rotorcraft or a tethered aircraft other than a fixed-wing aircraft
C6	STS-02	Have a maximum ground speed in level flight of not more than 50 m/s

Table 13 Standard scenarios references and drone restriction

4.1.4.3 The Specific Operation Risk Assessment methodology (SORA)[21]

This methodology is one of the risk assessment methodology that an operator should use when intending to fly a drone in the specific category of operation.

For the current SORA, the air and ground risks involved by several UAS flights are not considered.

The methodology consists of determining:

- An intrinsic Ground Risk Class number (GRC) which depends on the environment overflown and some physical characteristics of the drone
- A final Ground Risk Class after mitigation (e.g. emergency response plan in place)
- An initial Air Risk Class number (ARC) which depends on the air environment where the drone intends to fly (e.g. controlled airspace, uncontrolled airspace).
- Determination of the Tactical Mitigation Performance Requirement (TMPR)
- The Specific Assurance and Integrity Levels (SAIL) number, which defines how dangerous is the operation

- Identification of Operational Safety Objectives (OSO) with regards to the SAIL number

Both ARC and GRC are concerned by urban and/or populated environment.

For ARC, the main reason is that many cities are in or close to a Controlled Traffic Region (CTR) or entail helicopter operation from hospital's heliport for instance.

For GRC, the table below shows clearly in blue, that the higher risk level occurs in populated environment, and is even increased with increasing vehicle dimensions.

Intrinsic UAS Ground Risk Class				
Max UAS characteristics dimension	1 m / approx. 3ft	3 m / approx. 10ft	8 m / approx. 25ft	>8 m / approx. 25ft
Typical kinetic energy expected	< 700 J (approx. 529 Ft Lb)	< 34 KJ (approx. 25000 Ft Lb)	< 1084 KJ (approx. 800000 Ft Lb)	> 1084 KJ (approx. 800000 Ft Lb)
Operational scenarios				
VLOS/BVLOS over controlled ground area	1	2	3	4
VLOS in sparsely populated environment	2	3	4	5
BVLOS in sparsely populated environment	3	4	5	6
VLOS in populated environment	4	5	6	8
BVLOS in populated environment	5	6	8	10
VLOS over gathering of people	7			
BVLOS over gathering of people	8			

Table 14 SORA Intrinsic Ground Risk Classes (GRC) determination – JARUS Guidelines on Specific Operations Risk Assessment (SORA) JAR –DEL –WG6 – D.04

4.1.5 Operations in the certified category

A UAS is flying in the certified category of operation only when the following requirements are met:

- the UAS is certified pursuant to points (a), (b) and (c) of paragraph 1 of Article 40 of Regulation (UE) 2019/945EU and

- the operation is conducted in any of the following conditions:
  - over assemblies of people;
  - involves the transport of people;
  - involves the carriage of dangerous goods, that may result in high risk for third parties in case of accident.

In addition, UAS operations shall be classified as UAS operations in the 'certified' category where the competent authority, based on the risk assessment provided for in Article 11 of (EU) 2019/947 for an operation in the specific category, considers that the risk of the operation cannot be adequately mitigated without the certification of the UAS and of the UAS operator and, where applicable, without the licensing of the remote pilot

4.1.6 EASA Opinion 01/2020[6]

This document is introducing a high level regulatory framework of U-space. The following major ideas are exposed:

- A Common Information Service (CIS) that will enable the exchange of essential information between the U-space service providers (USSPs), the UAS operators, the air navigation service providers (ANSPs) and all other participants in the U-space airspace. There could be several CIS per country but only one CIS per U-space airspace.
- Until new systems such as Detect And Avoid or Sense And Avoid are available, all UAS shall be cooperative.
- Manned aircraft aiming to fly in a U-space airspace in an uncontrolled airspace needs to make available their position so that the UAS can avoid it.
- Four services are mandatory: network identification, geo-awareness, traffic information and UAS flight authorization. Three other services may be required to provide the four above: tracking, weather and conformance monitoring.

4.2 US regulation

Small UAS operations fall under different regulations depending on their details. They are:

[6] The present text does not take into account the last version of the regulation which may be published during the first quarter of 2021, after the delivery of this deliverable.

FAA Reauthorization Act of 2018[23] which re-authorises the FAA to perform its various functions and sets out what these are. *Unmanned Aircraft Systems* and *Drones* are mentioned at different points.

Title 14 CFR - Aeronautics and Space is one of fifty titles comprising the United States Code of Federal Regulations (CFR). Title 14 is the principle set of rules and regulations issued by the Department of Transportation and Federal Aviation Administration, federal agencies of the United States regarding Aeronautics and Space. The Federal Aviation Rules (FARs) are organized into sections, called *parts* due to their organization within the CFR. Each part deals with a specific type of activity. Part 107 contains rules for Small Unmanned Aircraft Systems [24]

4.2.1 UAS / Drones in FAA Reauthorization Act of 2018

UAS operations for recreational purposes are covered by the FAA Reauthorization Act of 2018. The act extends of more than 400 pages and mentions **drone** or **unmanned** in various places. Key requirements on recreational drone operators are

- registration of the drone
- mark the drone with its registration
- avoid restricted areas – these areas are presented in a web application
- do not fly over people of moving vehicles
- VLOS operation in daylight, below 400 feet and in class G airspace

There are various processes to avoid some of those last constraints in some circumstances.

4.2.2 Federal Aviation Administration Part 107[24]

Small Unmanned Aircraft Systems “Part 107” is a set of rules for Small Unmanned Aircraft Systems and concerns operations by certified remote pilots including commercial operators.

Two modes are foreseen, in the default, all sections of Part 107 apply. In the second, some sections can be waived (not applied) as a result of a waiver process.

4.2.2.1 Part 107

Part 107 is a set of rules for drone flight. It requires that the pilot is certified by means of an on-line test of these rules. Operation requires a registered drone, marked with its registration.

A very brief summary of some rules in part 107 follows:

- Unmanned aircraft must weigh less than 55 lbs. (25 kg).
- Operations are Visual line-of-sight (VLOS) only, either in site of the pilot or an observer, with unaided vision
- no operations
- over people not directly participating in the operation
- under a covered structure

- inside a covered stationary vehicle.
- Daylight-only operations, or twilight with appropriate anti-collision lighting.
- Must yield right of way to other aircraft.
- May use visual observer (VO) but not required.
- First-person view camera cannot satisfy “see-and-avoid” requirement but can be used as long as requirement is satisfied in other ways.
- Maximum groundspeed of 100 mph (87 knots).
- Maximum altitude of 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure.
- Minimum weather visibility of 3 miles from control station.
- Operations in Class B, C, D and E airspace are allowed with the required ATC permission.
- Operations in Class G airspace are allowed without ATC permission.
- No person may act as a remote pilot in command or VO for more than one unmanned aircraft operation at one time.
- No operations from a moving aircraft.
- No operations from a moving vehicle unless the operation is over a sparsely populated area.
- No careless or reckless operations.
- No carriage of hazardous materials.
- Requires pre-flight inspection by the remote pilot in command.
- A person may not operate a small unmanned aircraft if he or she knows or has reason to know of any physical or mental condition that would interfere with the safe operation of a small UAS.
- Foreign-registered small unmanned aircraft are allowed to operate under part 107 if they satisfy the requirements of part 375.
- External load operations are allowed if the object being carried by the unmanned aircraft is securely attached and does not adversely affect the flight characteristics or controllability of the aircraft.
- Transportation of property for compensation or hire allowed provided that.
- The aircraft, including its attached systems, payload and cargo weigh less than 55 pounds total.
- The flight is conducted within visual line of sight and not from a moving vehicle or aircraft; and
- The flight occurs wholly within the bounds of a State ….

Most of the restrictions above are waivable if the applicant demonstrates that his or her operation can safely be conducted under the terms of a certificate of waiver.

Some common examples of Part 107 sections that are subject to waiver:

- Operation from a moving vehicle or aircraft (§ 107.25)
- Daylight operation (§ 107.29)
- Visual line of sight aircraft operation (§ 107.31)
- Visual observer (§ 107.33)
- Operation of multiple small unmanned aircraft systems (§ 107.35)
- Yielding the right of way (§ 107.37(a))
- Operation over people (§ 107.39)
- Operation in certain airspace (§ 107.41)
- Operating limitations for small unmanned aircraft (§ 107.51)

The process of applying for a waiver includes the generation by the drone operator of a safety justification and acceptance of that justification by the FAA. To an extent there is some parallel with SORA and the European notion of Specific operations in that the operation is examined, risks are identified, and mitigations may be proposed.

4.2.3 Notice of proposed rule-making 2019 – 28100

Expected to give rise to a law at the end of 2020 or in early 2021, NPRM 2019-28100 describes how all drones shall be subject to remote identification, including network remote identification. As a result, apart from some limited exceptions, all drones must, at all times during flight, continuously transmit their position to a UTM service provider.

In effect this proposed regulation will lead to a situation where virtually all drone flights are being tracked. Although the NPRM does not discuss the applications of the tracks, many can be foreseen in regard to flight safety.

4.3 European regulation for manned aircraft operations in urban area (e.g., SERA), specific national regulation

General rules are defined in the Standardized European Rules of the Air (SERA) [25].

Rules depend whether the aircraft flies in IFR or VFR on one hand, and whether the aircraft flies at day or night.

4.3.1 Minimum heights

4.3.1.1 European Rules

4.3.1.1.1 The aircraft flies with instrument Flight Rules

Except when necessary for take-off or landing, or except when specifically authorized by the competent authority, an IFR flight shall be flown at a level which is not below the minimum flight altitude established by the State whose territory is overflown, or, where no such minimum flight altitude has been established at a level which is at least 300 m (1 000 ft) above the highest obstacle located within 8 km of the estimated position of the aircraft [6]

RPAS flying in controlled airspace are considered as flying in IFR. These aircraft are usually state aircraft (military) and their flight in civil controlled airspace requires coordination between the operator (usually the military) and the air traffic control. Hence, as considered flying in IFR, IFR apply to the RPAS.

4.3.1.1.2 The aircraft flies with the Visual Flight Rules

4.3.1.1.2.1 At nighttime

VFR flights between sunset and sunrise, or such other period between sunset and sunrise as may be prescribed by the appropriate ATS authority, shall be operated in accordance with the conditions prescribed by such authority [6].

Except when necessary for take-off or landing, or except when specifically authorized by the competent authority, a VFR flight at night shall be flown at a level which is not below the minimum flight altitude established by the State whose territory is overflown, or, where no such minimum flight altitude has been established, at a level which is at least 300 m (1 000 ft ; 1500 ft out of published routes in France for fixed wing aircraft –SERA FRA.5005 c)4)) above the highest obstacle located within 8 km of the estimated position of the aircraft.(SERA.5005 (5) ii)[25]

In France, in case of a balloon, the highest obstacle is the one situated at a flying distance of 10 minutes around the aircraft (SERA FRA.5005 c)4)) [25]

In case of a helicopter, the minimum height is 300m (1000 ft) above the highest obstacle which is the one situated at a flying distance of 1 minutes around the aircraft, out of published routes (SERA FRA.5005 c)4)) [25]

4.3.1.1.2.2 At daytime

Except when necessary for take-off or landing, or except by permission from the appropriate authority, a VFR flight shall not be flown over the congested areas of cities, towns or settlements or over an open-air assembly of persons at a height less than 300 m (1 000 ft) above the highest obstacle within a radius of 600 m from the aircraft [6] [25]

4.3.1.2 Specific national regulation (case of France)

4.3.1.2.1 For VFR

Some countries impose additional restrictions to SERA. One of them for instance in France, is to forbid an aircraft in VFR to overfly a populated area below a certain height. This minimum height depends on the size of the populated area overflown. Minimum heights are as per the below table:

Size of urban area	Minimum height
Small built-up areas used for navigation landmarks (e.g., isolated manufacture, industrial building, hospital)	1000 feet for single piston engine aircraft 3300 feet for the other
Small built-up areas less than 1200 m mean wide and assembly of people or animals (e.g., beaches, stadium, public meetings, hippodromes)	1700 feet for single piston engine aircraft 3300 feet for the other
Medium built-up areas between 1200 m and 3600 m mean wide and assembly of at least 10000 people	3300 feet for all aircraft except helicopter
Large built-up areas more than 3600 m and assembly of at least 100000 people	5000 feet for all aircraft except helicopter
The city of Paris	6600 feet

Table 15 Minimum heights over urban area in France

4.3.1.2.2 For non-propelled aircraft

Except for the needs of take-off and landing and maneuvers inherent to these flight phases, non-propelled aircraft are not allowed to fly over urban areas and assembly of people in open-air areas, except if it stays at a height which allows to land without endangering people and properties on ground. This height is not below 300 meters above the highest obstacle 600 meters around the position of the aircraft.

4.3.1.2.3 For helicopter

Whatever the provided authorization allows the helicopter to descent, the operator shall always be sure that the helicopter will be able, in case of urgency, to leave the urban area, or reach a landing area in the urban area, without endangering people and properties on ground. Thus, to overfly an urban area, depending on the aircraft, its technical characteristics, the operator will define minimum heights for each portion of the trajectory allowing the aircraft to land outside the urban area or on a public area/aerodrome in case of engine failure. Will be included the capacity of the aircraft to hover with the meteorological conditions the day of the flight.

4.3.1.2.4 For aircraft with specific authorization

Size of urban area	Minimum height for day shooting in VFR	Minimum height for night shooting in VFR

Small built-up areas used for navigation landmarks (e.g., isolated manufacture, industrial building, hospital)	300m for single engine aircraft 182m for the other	600m Multi engine aircraft:450m Multi engine helicopter: 300m
Small built-up areas less than 1200 m mean wide and assembly of people or animals (e.g., beaches, stadium, public meetings, hippodromes)	400m for single engine aircraft 200m for the other	
Medium built-up areas between 1200 m and 3600 m mean wide and assembly of at least 10000 people	500m for single engine aircraft 200 m for the other	
Large built-up areas more than 3600 m and assembly of at least 100000 people	1500m for all aircraft except helicopter	

Table 16 Minimum heights over urban areas in France for aircraft with special authorization

4.3.2 Rules of the air

4.3.2.1 Flight plan

A pilot who intends to fly with Instruments Flight Rules shall submit a flight plan at least 60 minutes before departure.

The same pilot wishing to fly with Visual Flight Rules can submit a flight plan, but it is mandatory only:

- for flight at night if the flight is not local

- if the aircraft flies over water or regions designated by aeronautical information

- if the aircraft crosses a border.

VFR flights are forbidden in airspace of class A.

Hence, it will be impossible to strategically de-conflict drone operations and manned aircraft operations whose intents are unknown well in advance. Generally, intentions of the VFR pilot are communicated to the controller through the first radio contact.

4.3.2.2 Collision avoidance

"Nothing shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action including collision avoidance maneuvers based on resolution advisories provided by ACAS equipment, as will best avert collision" [6]

As mentioned, several times in the different literatures, this is quite hard for a pilot of a manned aircraft to see drone in the sky due specifically to the small size of the drone first, and to the fact that the pilot has to concentrate on its own operation while being close to the ground.

Hence, avoidance of collision between a manned aircraft and a drone shall be the responsibility of the remote pilot when the drone is flown VLOS. Nevertheless, the remote pilot flying a drone in VLOS in dense traffic conditions may take advantage of services such as a traffic information to help avoid collision.

If the drone is flown BVLOS, avoidance of collision will be provided by systems such as detect and avoid.

4.3.2.3 Right of way

The current EASA regulation provides no information on the right of way between manned and unmanned aircraft. You could make the assumption that priority will be given to aircraft which have people on-board or very sensitive payload such as medical goods.

4.3.2.4 VMC visibility and distance from cloud minima

Provided that aircraft flying in VFR are not allowed to overfly an urban area below 1000 feet (see table 2.2.1.2.1), this part of the rules of the air more concern VFR in the vicinity of an aerodrome for take-off, landing and aerodrome circuit.

Visibility and distance from cloud are clearly compatible with VLOS operations, BVLOS operations should not be impacted by these parameters.

Altitude band	Airspace class	Flight visibility	Distance from cloud
At and below 900 m (3 000 ft) AMSL, or 300 m (1 000 ft) above terrain, whichever is the higher	A***B C D E	5 km	1 500 m horizontally 300 m (1 000 ft) vertically
	F G	5 km	Clear of cloud and with the surface in sight

Table 17 Part of VMC visibility and distance from cloud minima table - ICAO Annex 2 [6]

4.3.3 The separation

The separation in the context of urban environment is quite sensitive. As we cannot talk of separation between drones and between drones and manned aircraft for the moment, we can only focus on the separation between manned aircraft.

When the flights occur in a non-controlled airspace, there is no flight in the VLL (considering it goes from the ground to 500 feet) except those authorized by the national regulations. These aircraft fly in VFR and their separation with other aircraft is visual.

If the flights occur in a controlled airspace, we can consider as flying in the VLL aircraft flying with visual flight rules or instrument flight rules and proceeding to the climb after take-off or in the final approach phase of the flight.

For the arrival sequence, aircraft will have been separated visually owing to traffic information and procedure, there is no figure for that separation; or by the approach applying radar separation. For radar separation, it depends on two parameters:

- how good the radar is able to separate two aircraft performing their approach, with usually a separation which is no less than 2, 5 – 3 NM and,

- the wake turbulence separation between two different categories of aircraft. This may significantly increase the separation, up to 6NM.

If no radar is used for separation, time between two landings must be at least 2 minutes.

-For the departure sequence, an aircraft can take-off as soon as the runway is vacated or if the previous aircraft has took-off. The wake turbulence separation must be applied as for the arrival. Usually, this separation is expressed in minutes and could be of 2 minutes to 3 minutes.

All the details can be found in the ICAO Doc 4444 [26]

4.3.4 In controlled airspace

Usually, the airports have been built quite far from the cities, for instance for economic reasons or to reduce the noise impact on population in an era where the aircraft were significantly noisier than today.

But during the last decades the cities expanded, and it is not rare today to have some parts of a city or even the whole urban area in a CTR.

Hence, parts of the city in the CTR may see aircraft authorized to fly below the minima described in section 2.2.1 during the take-off and first part of the climb phase, final approach and landing of an aircraft. Aircraft in the aerodrome circuit (e.g., downwind) will also fly below these minima. This concerns mainly the parts of the city close to the runway and departures and arrivals trajectories.

4.3.5 In uncontrolled airspace

If the urban area is not situated in a controlled airspace and without aerodrome in the vicinity, the minima are those define in SERA for the transit above urban area.

Sometimes there is an aerodrome close to a city, but the airspace is not controlled. The minima are those defined in SERA, except when necessary for take-off or landing, aerodrome circuit, or except when specifically authorized by the competent authority.

4.4 Regulations points of interest and identified research challenges

The consultancies of several entities (DSNA in France, AESA in Spain, the Ministry of transport in Germany and EASA) involved in the regulation domain show that the regulation of drone operations in urban environment is on progress but some domains still require some research. These domains, amongst other, are the following:

- Compatibility of drone flights with other aircraft and between them (U-space)
- Electromagnetic interferences

- Societal acceptance (e.g., noise, protection of privacy)
- Security including cyber-security
- Availability of take-off and landing zones in dense urbanized areas
- Safety
- Aerology
- Local weather phenomenon

European Union member states will play a significant role by designing the owner of the airspace and/or of the U-space airspace above cities.

The safety part is quite already integrated in the regulation with the risk assessment methodology SORA for the Specific category of operation. This category of operation could be authorized to fly over urban areas provided that the mitigations match with the highest level of requirements proposed by SORA for the SAIL number 6. Otherwise, urban operations will fall in the Certified category of operations.

If most operations are in the certified category, it would probably have a huge impact on the number of operations in urban environment, especially because of the cost it would engender on the operation itself (certification of the drone, of the operator, set of a maintenance program of the drone, etc...).

An interesting view from the Ministry of transport in Germany is the way Germany sees transportation of people by drones in the future. This transportation means is more seen as “flying buses” flying on predefined routes connecting one or several stations. This is in opposition with the “taxi-drone” concept taking-off from anywhere and landing everywhere possible.

This vision implies that the question of the availability of take-off and landing zones would not be a problem because their number would be limited.

4.5 Results of the surveys

Two surveys have been launched via the DACUS website. The first was dedicated to collect how drones and drone operations are seen by citizens. The second aimed at collecting the vision some European cities’ authorities have of U-space and drone operations.

4.5.1 Surveys on citizens

4.5.1.1 Introduction to the results

The survey was composed of fourteen questions and was available on the DACUS website in three different languages (English, German and French). DACUS partners were asked to motivate their relationship to reply.

The objectives of the survey were to get an overview of:

- the general perception citizens have on drone operations
- and what could possibly slow down unmanned operations over urban environment.

We collected answers from 165 participants. Some information about the participants:

- Half of the participants are less than 30 years old and 88% are less than 60 years old.
- 69% live in an urbanized area with more than 20000 inhabitants
- 95% went to college and further

4.5.1.2 Main ideas

The complete results can be found in appendix B.

The statements in the next paragraph need to be considered having in mind that:

- 45% of the participants consider that they are well informed about new technologies
- 80% have no experience with drones or responded neutral at question 3
- 35% are interested by drone

Generalities on operations:

- 33% agree with drone operations in urban environment, 32% disagree but 35% are neutral. Nevertheless 56% think drones will make their life easier and 62% say they will use services provided by drones. Maybe more communication around what drones could bring may balance the neutral to the first group.

Regarding the societal impact:

- 69% do not want drones to fly over their property and 60% do not feel well near a drone, 36% because of safety consideration
- 40% are disturbed by noise emissions of a drone flying at 100m height mainly because they are surprised first, they think it could disturb a conversation or have an impact on their sleep.

4.5.2 Surveys on EIP - SCC initiative cities

4.5.2.1 Introduction to the results

A survey was available on the DACUS website and EIP SCC (European Innovation Partnership on Smart Cities and Communities) initiative cities were asked to reply to survey if they wanted to contribute.
Objectives were:

- to determine how far European cities were involved in U-space and drone operations
- to have information on what they are ready to do to foster the development of drone operations in urban environment

Unfortunately, we had few contributions, as only four cities replied to the survey. The results below can clearly not be generalized to all European cities, but at least provide some clues.

Cities which contributed are:

- Tampere – Finland – around 2270000 inhabitants in 2016
- City of Oulu - Finland – around 200000 inhabitants in 2016
- Wadern – Germany – Around 18000 inhabitants in December 2008
- Heidelberg – Germany – around 160000 inhabitants in 2019
- Toulouse – France – around 486000 inhabitants in 2018

Numbers of inhabitants concern the cities without the suburban areas.

The population of each city comes from the website Wikipedia. Provided that half of European cities are populated by more than 100 000 inhabitants (excluding the suburban areas), we could at least consider as relevant the answers to the surveys.
The surveys were divided into 13 multiple choices question and two open questions.

4.5.2.2 Main ideas

The complete results can be found in appendix A; if answers are sometimes quite different, we can come up with the following ideas:

- Most cities plan to develop or allow specific ground infrastructures for drone operations and they plan to develop or help the development of dedicated energy network for drone operations, within 5 to 10 year.

- Cities expect to forbid drone to fly over certain areas such as church, city centers, hospital, school, etc.…

- Most cities plan to impose minimum height or lateral distance between drone and buildings to prevent visual and noise pollution. They probably need to get more visibility on the amount of drone operations that will occur and have more information about the noise produced by drones.

- Most cities already have ideas on which use cases they will deploy, with a special focus on people care for Toulouse. First use cases will be deployed in the near future (5 years).

4.5.3 Impact on drone operations in urban environments and in demand & capacity balancing

4.5.3.1 European regulation and categories of operation

Despite EASA regulation is not complete, we can already deduce from it that operate in urban environment impose lots of constraints with regards to the ground risk.

Operations in the open category are possible but only in areas of the urban environment which are empty of people. We could imagine feasible operations in the open category related to bridge inspection, or operations at night in empty areas if the drone is made visible.
The second option would be to get an authorization to “close” a street or a sidewalk where an operation is expected, so that the drone does not fly over uninvolved people.
With a safety assessment and the adequate mitigations, flying in the specific category in urban environment should not be a problem, same in the certified category.

Nevertheless, costs of mitigations or certifications should be a serious impediment to the development of these categories of operations.

4.5.3.1.1 Impact on demand and capacity

Demand
Constraints imposed to all categories of operations may impact negatively the demand of drone operations over urbanized areas.
Capacity
If most of the drones flying in urban environment are certified, the certification could bring confidence in navigation performances for instance, and allow smaller separation minima compared to those needed with uncertified aircraft. The capacity could then be increased.

4.5.3.2 Minimum heights and rules of the air for manned aircraft

The section 4.3.1 shows that the minimum flight height above urban areas is clearly well above the VLL top.
The margin took for VLOS operations in class G is 30 meters with the first flight height available for VFR.
It would seem logical to have the same margin for BVLOS flight over urban areas; it would also allow to set the minimum flight height at a level reducing noise and visual pollution, and it would increase safety by providing operators/drones with more time to trigger contingency/emergency procedures.

Specific regulations mentioned in the section 4.3.1.2 confirm the above statement regarding the maximum possible drone flight height. Operations with special authorizations also confirm that these operations have no impact on drone operations in urban environment (for the French case).

Manned aircraft rules of the air are not that constraining for unmanned operations, except the point on the collision avoidance. There are few chances that the pilot of a manned aircraft sees a drone while searching across the cockpit. Unmanned aircraft conspicuity, dedicated U-space services (e.g., traffic information) made available for manned aircraft pilot, or adapted separation minima shall provide the right situational awareness and safety margin.
We could add the drone operation plan, a kind of flight plan adapted to unmanned operation, which looks to be mandatory in areas where the traffic is supposed to be dense. This is a prerequisite to the use of a DCB service.

4.5.3.2.1 Impact on demand and capacity

Demand
The demand may be reduced for operations which need to fly very low (e.g., close to buildings for inspection) if the minimum flight height is set to low. But exemption is possible for that kind of operation. This restriction is probably of the local authority responsibility. Some operators may be refractory to fill a drone operation plan, but as this shall be a requirement to access the volume, this should not be a problem; the worst that could happen is to receive the drone operation plan late.

Weather meteorological conditions will for sure have an impact on the demand, but those develop in the annex 2 should not influence drone operations.
Capacity
The maximum flight height is 120m AGL. The airspace capacity could be extended in particular if certified drones are authorized to fly above 120m AGL and below 300m AGL, keeping a margin with the first heights available for manned aircraft. Weather meteorological conditions will for sure have an impact on the capacity, but those develop in the annex 2 should not influence drone operations. Separations in controlled airspace between drones and manned aircraft should reduce the capacity of the controlled airspace for drone operations if the minima are increased.

4.6 Analysis of gaps and proposals

4.6.1.1 Minimum distance from people for Specific and Certified operation categories

The first gap identified is the lack of regulation for operations in the specific and certified categories related to the minimum distance between the UAS and the people or an assembly of people, whereas it is defined in the open category.

Even if the operator, the UAS and the remote pilot are certified when operating above urban or populated environment, there should be minimum distances, vertical and horizontal, set between the UAS and obstacle, people and assembly of people.

4.6.1.2 There is no clear definition of populated area

EU regulations, acceptable means of compliance and guidance material [19] [20] mention “populated area” but do not refer to a precise definition of the term:

EASA is pursuing the Launch a study for a better measurement of population density in Europe, which include development of static and dynamic maps (EASA presentation of the 1st October 2020 – “Operations in the medium risk of the Specific category”).

4.6.1.3 The SORA does not consider air risk due to other UAS flight, only with manned aircraft.

JARUS WG 6 is already working to expand the scope of SORA to address the risk of collision when more UAS are flying in the same airspace (e.g. urban), but EASA considers that in the first phase, the number of UAS operations will not be too high, so this lack is not an issue for the moment.

This hypothesis is not compatible with DACUS which will consider several UAS flights for assessing the demand and the capacity.

5 Real Views of U-space Implementation in the Different Cities/Countries

The SESAR JU and many European projects (e.g., CORUS) provided some key elements and a general framework as a guide for the implementation of U-space across Europe.

Nevertheless, each country has its own view on how U-space will be developed and managed inside its airspaces, whether there are controlled or uncontrolled, over non-populated or urban areas.

The aim of this section is to depict how far some countries in Europe or outside go in the implementation of U-space for a while, with a focus on urban/populated areas.

In the sense of populated areas, we mean areas where the density of population is high for an undetermined duration; this exclude areas where the population density is temporarily high, such as beaches in summer or assembly of people during sport or entertainment exhibitions, just to name a few examples.

The table used to show the roadmap of each selected country is a summary of the information available on the website https://www.atmmasterplan.eu/depl/u-space. It shows the roadmap from year 2021 to 2024. For all the countries, years 2025 and 2026 do not show any difference with year 2024 and hence haves not been included in the table.

5.1 In France

5.1.1 The framework

The vision of DSNA is a federated organization of U-space Service providers. For the moment DSNA does not see itself has a direct U-space Service Provider, but more as a facilitator to access specific data for instance.

5.1.2 Demonstrations and operations in urban environment

The French Air Navigation Service Provider DSNA launched in 2019 a nationwide U-space pre-operational program (U-space together) on ten different sites, with partners such as Thales, Airmap, Clearance, Airbus or Sopra Steria, to test and develop the provision of U-space services in controlled airspaces, in addition to those where Clearance is already implemented.

Since a lot of urban areas are in a CTR, the demonstration allows operator to request the prefectoral authorization through the procedural interface.

This program aims at improving the current solutions and proposes provision of new U-space services.

5.1.3 Services implementation and roadmap

Figure 11 Alpha Tango login page

U-space implementation in France has begun with the registration service through the Alpha Tango application (the former "mon espace drone") in 2018. From 31 December 2020, according to the European regulation, all UAS operators, professional or recreational, will have to register if the drone's weight is above 250g, operating in the open category of operation, have in case of an impact with human a kinetic energy above 80 j and is equipped with a sensor able to capture personal data, unless it complies with Directive 2009/48/EC on the safety of toys7.
Recreational users must consult the geoportal website (https://www.geoportail.gouv.fr/) to visualize where they are allowed to fly and at which height. Controlled airspaces and populated areas are forbidden.

On the other hand, a professional operator can fly in controlled airspaces if authorized by ATC or fly overpopulated area with a prefectoral authorization plus other specific constraints (e.g. VLOS only).
The Clearance application is already in service in 26 French airports and provide the services flight planning management, aeronautical information and procedural interface to the ATC for drone flights in controlled airspaces (mostly in Control Traffic Region).

Figure 12 Geo-portal recreational drone usage zones restrictions map

The roadmap as available on https://www.atmmasterplan.eu/depl/u-space

Services	2021	2022	2023	2024
e-registration				
e-identification				
Pre-tactical geo-fencing				
Tactical geo-fencing				
Flight planning management				
Weather information				
tracking				

Monitoring				
Drone aeronautical information				
Procedural interface with ATC				
Emergency management				
Strategic de-confliction				
Dynamic geo-fencing				
Collaborative interface with ATC				
Tactical de-confliction				
Dynamic capacity management				

Table 18 U-space services implementation roadmap - France

not yet planned on going planned completed

5.2 In Germany

5.2.1 The framework

In Germany, the ANSP DFS Deutsche Flugsicherung has made the choice to involve itself as a central entity of U-space. For CIS-Services, DFS is preparing to provide services to U-Space, e.g., other USSPs. Additionally, in order to differentiate the activities in ATM and UTM, a company has been created with Deutsche Telekom AG: Droniq.

Droniq will provide a set of services (map data, traffic information, procedural interface with ANSP) to operators – and as such it acts as an USSP as well. Droniq systems will use DFS systems and have access to the DFS cloud where traffic information is stored. This will concern all kind of tracks, from radar, ADS-B, Flarm or hook-on device using GSM LTE 5G, coming from manned or unmanned aircraft.

5.2.2 Demonstrations and operations in urban environment

A demonstration of the concept will be performed from December 2020 to June 2021 in Hamburg.

Drones will fly in special activity areas, temporary activated.

Subsequently, a demonstration of an urban mobility solution is planned in Frankfurt with Volocopter, linking the financial quarter to the airport. The route has been designed in order to not overfly the urban areas, by overflying only the Main River and a forest. This solution is based on use of corridors as protected areas. Nevertheless, it looks like German cities are ready to invest for urban drone operations. The DFS will support that demonstration and provide UTM services.

5.2.3 The services implementation and roadmap

Finally, the registration service will be managed by the LBA (Luftfahrtbundesamt), with a start on January 2021, as per the European regulation.

Period / Domain	2019 -Initial provision of service	2020 - Expansion of service portfolio	2021 - Further development of reach	2022 – Fully integrated platform solution
UTM System	Live Air Traffic Display as UTM Beta Version	Registration & Mission Planning	Mission clearance & conflict warning	Mission evaluation & documentation
LTE solution	Locating the UAS via hook-on device & ground sensors	Full integration into the aircraft	Integration of Command & Control	Real-time data transfer
Data & Services	Training & Consulting for UAS Missions	Integration of drone detection systems	Offers for Data Analytics & Insurance	Integration of E-Identification Broadcast

Table 19 UTM systems, LTE solution and Data services implementation roadmap in Germany - available on https://droniq.de

This roadmap as available on https://www.atmmasterplan.eu/depl/u-space

Services	2021	2022	2023	2024
e-registration				
e-identification				
Pre-tactical geo-fencing				
Tactical geo-fencing				
Flight planning management				
Weather information				
tracking				
monitoring				
Drone aeronautical information				

Procedural interface with ATC				
Emergency management				
Strategic de-confliction				
Dynamic geo-fencing				
Collaborative interface with ATC				
Tactical de-confliction				
Dynamic capacity management				

Table 20 U-space services implementation roadmap – Germany

not yet planned on going planned completed

5.3 In Italy

5.3.1 The framework

In short to middle terms, Italian authorities think that a centralized solution where one entity will provide at least the core services is the best option if we consider a quick service provision.

For other services, the market may be open to other actors.

At longer terms, Italy will refer and align to the European regulation once published.

5.3.2 Demonstrations and operations in urban environment

For the moment, the issue does not seem to be on the traffic management side but rather on the airworthiness of UAS and the acquisition of operational authorizations.

Nevertheless, as soon as this blocking issue is resolved, the demand will increase quickly and then an evolution is required taking measures in this more congested environment. Strategic measures and relying on more performing identification and tracking systems are a minimum, whereas Detect And Avoid (DAA) and vehicle to vehicle (V2V) interactions will enable early tactical de-confliction techniques.

5.3.3 The services implementation and roadmap

The services of registration and publication of geo-awareness data were implemented.
An application hosted in the D-flight portal allows operators to plan their operation in order to guarantee a geo-temporal spacing between planned operations. This procedure makes possible short BVLOS operation, for instance in proximity of obstacles, with visual observers.

The portal may also possibly host a service to notify the activation and completion of an operation in order to surrogate the tracking service until it is available. At least it provides when a piece of airspace is occupied.
The intention is to deploy soon a U-space solution which enable all BVLOS which are operationally allowable. It would complete mainly U2 set of services.

The roadmap as available on https://www.atmmasterplan.eu/depl/u-space

Services	2021	2022	2023	2024
e-registration	on going	completed	completed	completed
e-identification	on going	completed	completed	completed
Pre-tactical geo-fencing	completed	completed	completed	completed
Tactical geo-fencing	completed	completed	completed	completed
Flight planning management	on going	completed	completed	completed
Weather information	on going	completed	completed	completed
tracking	planned	completed	completed	completed
monitoring	planned	completed	completed	completed
Drone aeronautical information	not yet planned	not yet planned	not yet planned	not yet planned
Procedural interface with ATC	completed	completed	completed	completed
Emergency management	planned	completed	completed	completed
Strategic de-confliction	on going	on going	on going	on going
Dynamic geo-fencing	not yet planned	not yet planned	not yet planned	not yet planned
Collaborative interface with ATC	planned	on going	on going	on going
Tactical de-confliction	not yet planned	not yet planned	not yet planned	not yet planned
Dynamic capacity management	not yet planned	not yet planned	not yet planned	not yet planned

Table 21 U-space services implementation roadmap – Italy

not yet planned | on going | planned | completed

5.4 In Spain

5.4.1 The framework

Spain wishes to implement a federated U-space where ENAIRE would act as the national Common information Service provider (CISP), and a provider of critical services. Air Traffic Management, privileged users and authorities and U-space Service Providers would be directly linked to the national CISP.

ENAIRE is also aware that a service offer based on commercial incentives may lead to one or several U-space service desert(s). That is why ENAIRE envisaged to have a role as U-space service provider in order to ensure U-space services are provided to all users.

5.4.2 Demonstrations and operations in urban environment

ENAIRE got a lot of experience by participating in the DOMUS project. This project allowed the demonstration of U-space initial services U1 and U2 and some specific U3 services such as collaborative ATM and tactical de-confliction. Smart city use cases were performed and three different USPs were providing services in the same area.

There is no specific demonstration scheduled for the moment in Spain but ENAIRE will contribute to the projects CORUS X Urban Air Mobility in early 2021 (CONOPS), USPACE4UAM (AIS database, Gamma Sim) and AMULED in 2022(Demonstration facilitator).
ENAIRE's vision for flight authorizations in urban environment, especially those taking place in Controlled Traffic Region, is close to the US LAANC.
Depending on the distance from the airport, a limited flight height for drone operation will be set and a digital coordination with ATM will be put in place.
For helicopter operations in the same area, a tool for ATC will allow coordination

5.4.3 The services implementation and roadmap

For the moment, the tool ENAIRE Drones, available on ENAIRE's website and with a mobile application, provides static and dynamic information, graphically displayed, on which areas are accessible for drone for recreational use.
In order to fly in controlled airspace, an authorization from AESA, the Spanish regulator, needs to be requested, as well as coordinated with the ATS provider in that airspace.
This coordination with ENAIRE can be carried out through the ENAIRE's tool PLANEA, which allows users to coordinate non-standard flights with ENAIRE.
Flight planning, aeronautical information and a national e-registration are the services already available in Spain.
European registration service should be possible in early 2021.
For BVLOS operations in class G airspace, a NOTAM must be issued in coordination with the Spanish Air Force.

The plan for the coming years is seen in two phases:

From 2020 to 2022, advanced functionalities compatible with EASA regulation will be implemented.
From 2023, ENAIRE plans to provide critical U-space Services through the Common Information Service, as a CIS-P.

During the first phase, the following services may be proposed, some with operational limitations and other because not enough defined by the European regulation:

E-registration, e-identification, geo-awareness, tactical geo-fencing, tracking, weather information (same as manned for the moment), drone aeronautical information, flight planning management, procedural interface with ATC (limited for the moment), emergency management, monitoring, traffic information, collaborative interface with ATC and tactical de-confliction.

This roadmap as available on https://www.atmmasterplan.eu/depl/u-space

Services	2021	2022	2023	2024
e-registration				
e-identification				
Pre-tactical geo-fencing				
Tactical geo-fencing				
Flight planning management				
Weather information				
tracking				
monitoring				
Drone aeronautical information				
Procedural interface with ATC				
Emergency management				
Strategic de-confliction				
Dynamic geo-fencing				
Collaborative interface with ATC				
Tactical de-confliction				
Dynamic capacity management				

Table 22 U-space services implementation roadmap – Spain

not yet planned on going planned completed

6 Airspace Structures and air rules models

Based on the content of the previous sections of this document, this chapter will provide three different models of U-space urban environment taking into consideration the level of constraints imposed to the drone operator.

The elements which define the level of constraint are picked in the three different environment characterisations developed in sections 3, 4 and 5. The models should provide a framework for the future design of airspace environments for certain urban areas. Below a schema showing the methodology used for modelling:

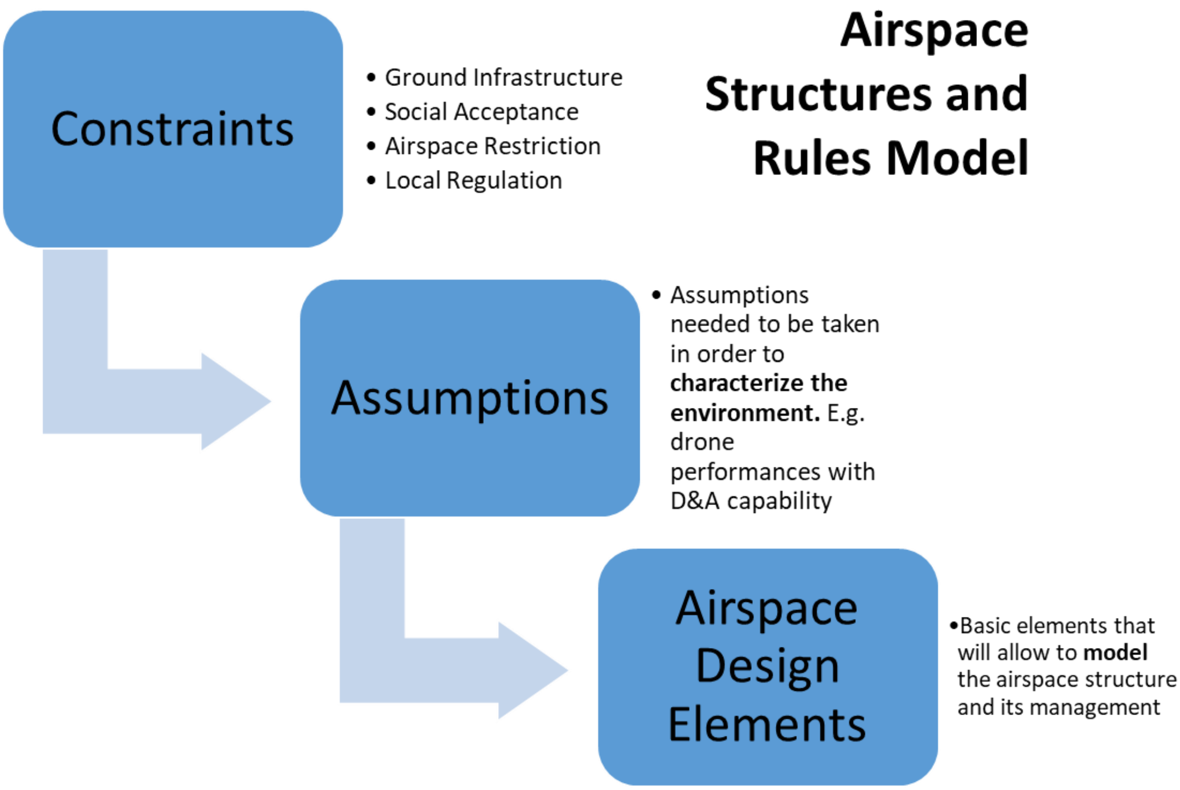


Figure 13 Modelling methodology

The first model considers low level of constraints while the third model includes several constraints seen as quite constraining for a drone operation.
A medium proposal set some principles describing an airspace structure and rules of the air with a mix of areas where the flows are separated and organised and other areas where some freedom are given to the operators due to more adapted ground structure. The consideration of mixed areas is motivated by the different types of urbanized regions to be found in European cities and the diversity of urban areas within (see §3.1).

6.1 Model with a set of low- level constraints

Low level of constraints means that for an operator, organising and performing a drone operation will be as easy as possible. This environment promotes demand in drone operations of all types and may provide maximum airspace capacity in a way or another.

This “beneficial environment” for drone operation, considering that the level of safety is at an acceptable level as much for the other drone operations as for manned aviation, would be as follow:

Ground infrastructures

The drones could take-off and land everywhere. In §3.1.1, different types of urban areas are described, and it is evident that in some of them it will still be very unlikely to deploy drone operations without exceptional permissions (e.g. airports), but in general it is assumed that drone operations can be approved in most of the areas. For instance, each citizen may have his package delivered in front of his door.

Societal acceptance

Drones are societally very well accepted because people see all the benefits they can receive from drone operations, thanks to all possible drone usages. From the survey on the acceptance of drone operations in §4.5.1, there is a general positive response from the citizens on using drones in public areas and the benefit that their use and derived services represent. Hence, they accept noise and visual pollutions as well as some accidents which could, rarely, occur.

Airspace restrictions and structures

- Airspace structures and traffic management do not impose specific restrictions such as speed limitation. Limitations may come from other parties such as insurance companies.
- Close coordination is made between USPs and the other entities managing sensitive areas (e.g., school, prison, hospital) and airport.
- No drone zones are activated only when occupied by a manned aircraft. This concept is more or less based on a kind of smart segregation. This allows a maximum use of airspace in order to increase capacity.
- No routes imposed (free flight is the rule, see free/direct routing strategy in §3.2.4), even operations close to airport and high manned aviation traffic density are allowed thanks to ATC collaborative interface, efficient drone detection means and on-board “detect/sense and avoid like” equipment(see §3.4.7).
- Airspace structures(e.g., corridors) for drones only transiting in the airspace above the urban environment for instance, could be activated to organize the flows.

Local regulation

Local regulation is very permissive: there is no curfew (drones can fly 24/7: surveillance operation, medical usage for instance have convinced citizens that drones can save lives). Only European regulation is applied regarding safety and considered as sufficient. The Commission lets the societal part on national/local regulators responsibilities.

Communication, Navigation, Surveillance

The communication network is good enough to allow a lot of drone operations at the same time; When C2 link fails for drone manually steered, the drone shifts automatically in autonomous mode with a high level of safety.
Ground based augmentation systems provide the drone with a high navigation accuracy, allowing to set the lowest separation minima with other aircraft, thus with obstacles. This implies that there is a high performance of the key performance parameters described in §3.3.
Technology brought the solution to detect non-collaborative drones in particular those used maliciously. Most drones are collaborative.

6.1.1 Rules of the air and U-space service

- All U-space services are available. Drone operations must be declared and require USP authorization to proceed.
- Separations are performed by the strategic, tactical conflict resolution service and DCB services.
- All drones are equipped with on-board "detect/sense and avoid like" systems for collision avoidance.
- Drones carrying sensitive goods such passengers, blood or any medical stuffs have priority on the other flights. State operations have priority on passenger transportation.
- VLOS and BVLOS flights are authorized according to the EASA regulation. Certified and some specific categories of operations with standard scenarios are possible above densely populated areas.
- There is no limitation on meteorological conditions except those directly linked to each drone performances (e.g., temperature, wind).

6.1.2 Required design elements and suitable implementation concepts

This model is compatible with the U-space ConOps as long as the urban area is included in a Zu or Za volume, where the tactical conflict resolution service is provided and adapted drone performances and equipment requirements are met.
Volume "Y" is not adapted to an airspace where the DCB service could be useful, because of the amount of drone operations. Indeed, "Y" volume limits the traffic density as any tactical conflict resolution service should not be available. Hence, there is few chance that a demand and capacity balancing service is required/useful.

6.1.3 Pros and cons of the model with low level of constraints

The following table summarizes certain advantages and disadvantages in regard to resulting future drone traffic in urban areas, in particular those which are relevant for the DCB processes.

Ground infrastructures

Pros	Cons
Abundance of take-off and landing areas may dramatically increase the possibilities of drone operations.	DCB measures would be so often implemented that operators could be upset because of systematic changes in their plan.
Societal acceptance	
Pros	Cons
All drone operations are well accepted which opens a lot of business possibilities.	This good acceptance of drone operations shall not impact the goal to maintain a high level of safety, requiring to implement advanced technologies
Airspace restrictions and structures	
Pros	Cons
Free route allows direct trip from point to point and increase the operating range of drone. It also simplifies the preparation of an operation. Activation or deactivation of specific airspace structure as a DCB measure may increase or decrease the capacity.	The free route concept might decrease the capacity of a volume and increase the number of hotspots (to be further analyzed within the DACUS project). Hence, DCB measures should be activated more often and some of them could not be applicable.
Local regulation	
Pros	Cons
We do not see specific pros or cons.	
Communication, Navigation, Surveillance	
Pros	Cons
The context described in this model allows a maximum number of operations.	It looks like there is no margin to increase the capacity unless by improving the technology. High infrastructure and maintenance costs which might impact negatively the market entry of certain business models.

Table 23 pros and cons of low level of constraints model

6.2 Model with a set of medium level of constraints

This model provides structures and rules by separating activities based on ground risk considerations and societal impact on one hand, and on- air flows management on the other hand.

Ground infrastructures

Some specific areas in the city allow drone to take-off and land. These areas are mostly residential with low population density areas (e.g., with house and garden). Drones can land at a safe distance to lives and obstacles.
In other areas, where building and population densities are high, some adapted spots will be dedicated to drone operations (e.g., hubs, take-off and landing zones on building's roof) in order to limit ground risks.

Societal acceptance

Drones are societally well accepted, but people want to have some areas where drone activity is low. Locations such as parks in the city are closed to drone operations (e.g., no drone activity in and over the park) during lunch time and weekend.

Airspace restrictions and structures

- Corridors are in place in volumes where the traffic is dense (see corridor airspace structure concept in §3.2.4), especially when approaching take-off and landing spots in high building and population densities. It will help to separate, control and cadence air traffic movements.
- Corridors are also in place between "drone shuttle" stations linking activities centers. Only drones carrying passengers can fly in these corridors. A network of corridors dedicated to goods delivery between several industrial/working places has been set (see routes with grid-like structure concept in §3.2.4).
- Temporary no drone zones protect sensitive areas such prison, schools, hospitals, or cultural heritage buildings (see implementation of restricted zones in §3.2.4).
- Free routing is possible in the other remaining areas where any path is allowed

Local regulation

There are curfews in all residential areas when people are at home (e.g., early in the morning, evening, night and weekend). This could be a mechanism implemented by the local authorities in order to balance the interest of the citizens and the promotion of sustainable mobility (see §4.4)
Drone operations remain possible in industrial areas all day long, as long as nuisances are limited.

Communication, Navigation, Surveillance

The communication network is good enough to allow a lot of drone operations at the same time; when C2 link fails, the drone shifts automatically in autonomous mode with a high level of safety.
Navigation is made more accurate where drones are obliged to fly in corridors, because separation would need to be lower to allow more traffic but separation will have to be higher in free route airspaces.
Detecting non-collaborative drones in particular those used maliciously above the city still remain unaffordable for a lot of cities. This has been discussed in §3.3.3.
Airport are protected but not all the cities. Most drones are collaborative.

6.2.1 Rules of the air and U-space services

- U-space services are available and affordable for all operators and all drone operations must be declared and require USP authorization to proceed.
- Separations are performed by the strategic conflict resolution service and DCB services in corridors, and by strategic, tactical conflict resolution and DCB services in free route airspace parts.
- It is mandatory that all drones flying in the free route airspace areas are equipped with on-board “detect/sense and avoid like” systems for collision avoidance. This requirement is not mandatory for drones flying in corridors as flows are organized by the services of DCB and strategic conflict resolution.
- Drones carrying sensitive goods such passengers, blood or any medical stuffs have priority on the other flights. State operations have priority on passenger transportation.
- VLOS and BVLOS flights are authorized according to the EASA regulation, in free route airspace areas. In corridors, only BVLOS are allowed. Certified and some specific categories of operations with standard scenarios are possible above densely populated areas.
- There is no limitation on meteorological conditions except those directly linked to each drone performances (e.g., temperature, wind).

6.2.2 Required design elements and suitable implementation concepts

This model is not incompatible with the U-space ConOps airspace structure proposal, but limitations imposed to fly above areas where buildings and population are dense, with no matter of service provision, add constraints to this model.

6.2.3 Pros and cons of the model with medium level of constraints

Ground infrastructures	
Pros	Cons
Drone take-off and landing areas located in low population density zones will reduce ground risks and increase the capacity thanks to a better flows organization.	Limited take-off and landing areas will create bottlenecks for arrivals and departures and may increase noise and visual impact.
Societal acceptance	
Pros	Cons
In case of extreme necessity, temporary no-drone zones may be used to unblock a busy sector in coordination with the appropriate authority (similar to the current exemption from night curfews at airports).	Portions of airspace closed to drone operations during parts of the day will negatively impact the capacity and/or compel to create corridors away from those zones (to be further analyzed within the DACUS project).

Airspace restrictions and structures	
Pros	**Cons**
Corridors network will limit the population impacted by the nuisances and limit the number of conflict areas owing to an easier flow organization. Free routes where the traffic is less dense will provide more freedom to operator in the way to organize the operation and trajectory.	The same population will always be impacted by the nuisances. Potential conflicts at the limits of each routing structures could impact safety.
Local regulation	
Pros	**Cons**
The implementation of specific requirements such as stricter mitigations for ground risks and/or very low level of noise, could allow authorizing some operations during curfews.	These regulatory measures may imply that most of the drone operations are concentrated during periods with low restrictions.
Communication, Navigation, Surveillance	
Pros	**Cons**
Less requirements for cities and/or USSPs in the field of non-collaborative drone detection would reduce the cost of an initial U-space implementation.	The demand may be limited by requirements on navigation accuracy in corridors, or increase the cost of an operation. Lack of detection capacity will impact safety.

Table 24 Pros and cons of medium level of constraints model

6.3 Model with a set of high level of constraints

Even after years, technological locks are still in place and many challenges still remain to be taken on. Noise and visual pollution emitted by drone operations had a huge societal impact and strongly reduced the possibilities to fly over urban areas.
This environment does not encourage use of drones for many applications, but drone operations in the areas where they are authorized are numerous and require a high level of U-space services.

Ground infrastructures

Drones can take-off and land from and to a limited number of locations inside the urban area. Some ground hubs are in place to receive packages dropped by customers for sending or by drones for recipients.
Few take-off and landing zones allow passengers transportation between places such as airport and commercial centres.

All hubs and drone passenger stations are linked by a network of corridors(see corridor airspace structure concept in §3.2.4).

Societal acceptance

Drones are not societally accepted because of visual and noise pollution. Moreover, despite the high level of safety in drone operations, the proximity of drones, just few meters above or laterally all along their trip, implies lots of fear to people. From the survey on the acceptance of drone operations in §4.5.1, the citizens currently generally feel uncomfortable in the vicinity of drones and this feeling is not balanced by the argument that drones can save lives. If this does not change in the coming years, it could lead to a low social acceptance.

Airspace restrictions and structures

- In order to limit noise and visual pollution, routes are imposed in corridors and speeds are limited when overflying areas densely populated during the day to decrease noise impact(residential areas at night, early in the morning and in the evening, and commercial areas late in the morning and in afternoon).
- Permanent no drone zones protect sensitive areas such as hospitals, prisons, schools, parks, reducing the available capacity of the airspace. These no drone zones cannot be crossed at any time.
- Operations close to airport are nevertheless possible owing to a good coordination with ATC.

Local regulation

Curfews are in place everywhere during night and weekend. There is no distinction between residential and working areas during these periods.

Communication, Navigation, Surveillance

The communication network is good enough to allow a lot of drone operations at the same time; but poor navigation infrastructure and navigation performances require to implement high separation minima.
All drones must be collaborative as other solutions for surveillance and tracking purposes are not technically possible or not affordable.

6.3.1 Rules of the air and U-space services

- U-space services are available, but few competitors are in place and rates are not cheap. All drone operations must be declared and require USP authorization to proceed.

- Separations are performed by the strategic conflict resolution service and DCB services in corridors. Manned aircraft operations over the urban area other than those linked to the airport are segregated owing to temporary no drone zones.

- It is mandatory that all drones are equipped with on-board “detect/sense and avoid like” systems for collision avoidance, in case the tactical conflict resolution service fails.

- Separation minima with other aircraft and obstacles are high.

- Drones carrying sensitive goods such passengers, blood or any medical stuffs have priority on the other flights. State operations have priority on passenger transportation.
- VLOS and BVLOS flights are authorized according to the EASA regulation; in corridors, only BVLOS are allowed in the Certified category of operations. Some VLOS in the specific category with standard scenarios are possible above densely populated areas.
- There is no limitation on meteorological conditions except those directly linked to each drone performances (e.g., temperature, wind).

6.3.2 Required design elements and suitable implementation concepts

CORUS volumes proposal does not forbid any additional structures to improve the flows or to match with societal or safety concern.
In this model, no drone zones and corridors are mainly used.
This model clearly limits the potential of the airspace, mainly because technological solutions remain to be found or to be implemented.
Non implementation of the solutions available may come from financial reason or societal consideration.

6.3.3 Pros and cons of the model with high level of constraints

Ground infrastructures	
Pros	Cons
Limited drone operations infrastructures will allow a better and more efficient management of the flows.	This limitation may reduce the demand as some drone operations may not be possible in certain places. This limitation would also concentrate operations if peak hours. If the demand is too high, DCB measures may be triggered too often. Limited ground infrastructures will concentrate the traffic in few departure and arrival locations.
Societal acceptance	
Pros	Cons
This may dramatically limit the demand then DCB should not be triggered often. Hence, DCB should not heavily impact drone operations. This is a pros for operators.	For operators, this may dramatically limit the demand, hence the business opportunities
Airspace restrictions and structures	
Pros	Cons

Corridors network will limit the population impacted by the nuisances and limit the number of conflict areas owing to an easier flow organization. Corridors allow an efficient management of the flows by limiting the points of conflict and increase the capacity of a predefined volume.	DCB measure on drone's speeds will not be applicable if the speeds are to be increased. Limited airspace available impacts the capacity and there no possibility of loosening of no-fly zone.
Local regulation	
Pros	Cons
Emergency/state operations during the curfews periods will not be impacted by the demand.	Such measure will concentrate more operations between Monday and Friday increasing the demand during this period with the consequence to see the DCB measures implemented more often.
Communication, Navigation, Surveillance	
Pros	Cons
All drones are collaborative, which limits investments on operators side. Operators are rather independent from CNS infrastructure as they have more flexibility to choose their solutions.	High separation minima implies a reduction of the capacity (to be further analyzed within the DACUS project). Poor navigation infrastructures do not permit to require better navigation performances as a DCB measure to increase the capacity in a certain volume of airspace, or to reduce the demand. Investments limited on operators side may increase the cost of operations, decrease the demand and also decrease the business offer.

Table 25 Pros and cons of high level of constraints model

6.4 Roadmap for usage of the models

6.4.1 Through U-space implementation

The amount of unmanned aircraft traffic is not expected to be big at the very beginning of U-space implementation, mainly considering the few dedicated infrastructures in urban environment (e.g., CNS, take-off and landing areas) on one hand, and business opportunities which may imply in early U-space professional customers, on the other hand. We do not know yet exactly how drone operations will be accepted by the citizens as private customers and how long it will take for small businesses to implement drone services to the attention of individuals. Despite the different surveys performed, drone operations are still something abstract for citizens, and it is yet not clear everywhere who will make the required investments to develop drone operations.

Whatever the time it may take, but by considering the arguments above, we can assume that the model with a high level of constraints may be the kind of model in place over urbanized areas in the first implementation of U-space, meaning at short term.

The two other models, from the middle one to the first (with low level of constraints), would be implemented progressively while all necessary infrastructures are developed. This vision is more a long-term future.

For sure, trade-offs will have to be made between the degrees of freedom that the different stakeholders of U-space want to have and the minimum or optimized capacity of the urban airspace allowed by a model or another.

6.4.2 Within DACUS

A first draft of the Demand and Capacity Balancing (DCB) process has been proposed in the DACUS deliverable D1.1 as an initial proposal.

The process, owing to the development of several U-space services used by the service of Demand and Capacity Management service, will be tested in the WP4 activities through Fast Time Simulations (FTS).

The different characteristics/parameters of the models proposed will be used to characterize the urban environment of the tests, in order to see which model seems to be the most applicable and provide the best trade-off between demand and capacity according to the DCB measures that the model allows to apply.

It is likely that the models will be modified, refined or removed provided the results coming from the FTS.

The figure below summarizes the approach:

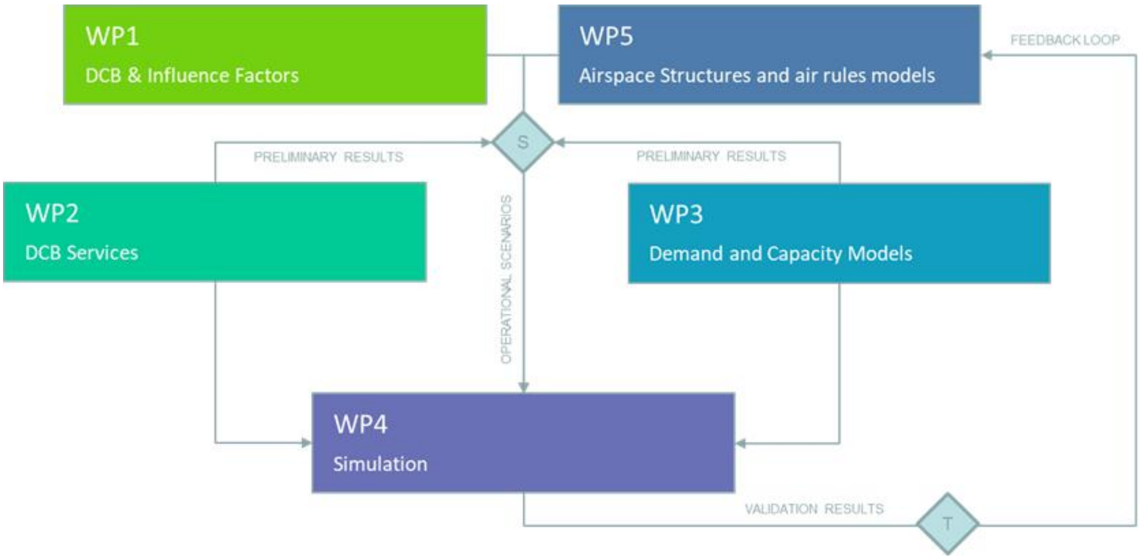


Figure 14 Models evolution-update-refinement approach

7 Conclusion

It appears that the current airspace and ground structures may be not adapted to drone operations in urban environment.

All the structures have been designed for quite big aircraft mainly dedicated to transportation of passengers and goods.

Aircraft flying over urban environment have specific authorizations to fly under the minimum height or they fly in the vicinity of an airport on pre-defined routes under the control of ATC. Manned aircraft are alone in the sky. They will have to share the volumes with unmanned aircraft, we do not know yet if manned and unmanned operations would have to be strictly segregated. Intentions were initially to integrate unmanned operations, with service such as the collaborative interface with ATC when the unmanned operation occurs in an airspace under the responsibility of an ANSP.

Whatever the solution, temporary or permanent airspace structures reserved to drone operations will have to be implemented, simply because some drone operations are totally different from those performed by manned aircraft, or at least will occur more often(e.g., building inspection, photography) over urbanized areas.

If manned aviation has at its disposal the airport runway(s) and some heliport, there is no ground structure dedicated to drone operations. The use of drones, particularly owing to their limited size (compared to manned aircraft) and VTOL configuration, allow them to operate in the middle of buildings with reduced infrastructures. Nevertheless, even these reduced infrastructures will be hard to build without impacting current ground structures, specifically when talking about old cities and their heritage.

Envisaged dedicated structures will also come from trade-offs between how and for what the drone is used. Having the possibility to take-off and land from everywhere would foster the drone market, whereas having limited structures, such as hubs for packages deliveries, may limit the demand.

The needs in communication, navigation and surveillance are key factors for drone operations. Some existing networks are available today for drone usage, but issues, some already known, other which studies are on-going, could negatively impact the drone market by limiting the number of drone operations in a same volume. Even if the results are positive for drone, costs linked to some technologies implementations may slow down the market by limiting the demand and the capacity.

The final point deals with the regulatory aspects, including the societal impact of drone operations in urban environment. Safety considerations are clearly a challenge, but noise, visual impact, and security (not addressed in this document)aspects are keys. The different surveys show that national and local authorities will have to deal with their citizens, however very interesting in what drones could bring to their daily lives.

The lack of data and information create a lot of uncertainties about how drones operations over urbanized areas will be possible. Lots of projects and studies are in progress, including the European regulation which will for sure impact the vision we can have today.

The market itself is uncertain and the number of recreational drones has not reached the forecast. Would it be the same for professional users?

If several assumptions must be made to draw a picture of drone operations, from strongly impacting to opening the possibilities, answers to some questions would help:

- Will drone operations be integrated or segregated from manned operations?
- What will be the investments in ground and CNS structures and who will make them(e.g., USP, ANSP, cities)?
- Will the citizens accept drone operations in term of noise and visual pollution, as well as the safety and security aspects?
- Will the European regulation be constraining to drone operations in urban environment for certified and specific categories of operations(e.g., development of more standard scenarios)?
- How much citizens' information on drone capabilities and services offer will increase or decrease their desire to use drones?

All these points will influence the capacity of an airspace volume, the demand generated by the potential customers and at the end the need in demand and capacity balancing as well as the DCB measures that might be put in place.

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Appendix A: Results of the survey on European cities

The first two questions aimed at knowing which city replied and if the responder was interested, involved or neither one nor the other in the development of drone operation in urban areas. Three replied involved and two interested.

Question 3: Does the city plan to develop or allow specific ground infrastructures for drone operations such as drone ports for drone or taxi drone, hubs for parcels deliveries, etc…?

Possible answers:

1 - yes, within existing infrastructures when space is available

2 - yes, in the place of existing infrastructure

3 - No, we do not plan to upset city infrastructure for drone operations

Question 4: Does the city plan to upgrade the communication network in order to foster and allow drone operations in urban environment?

Possible answers:

- yes, we will upgrade or help private companies to upgrade the network with specific authorization and/or financial contribution
- No, this is not the role of the city and/or the city cannot afford

Question 5: Does the city plan to develop or help to develop a dedicated energy network(gas, hydrogen, electric or other energy stations) for drone operation and in what timeframe?

Possible answers:

1 - Yes, and this network may also serve other transportation means ; as soon as possible

2 - Yes, and this network may also serve other transportation means ; within the next 5 years

3 - Yes, and this network may also serve other transportations means ; within the next 10 years

4 - No, this is not the role of the city and/or the city cannot afford

Question 6: Does the city authority expect to forbid the drone to overfly certain areas : for instance church, city centres, school, hospital?

- Yes, for safety, security and social impact reasons, during specific period of the day/week
- No, the European regulation is enough

Question 7: Does the city plan to impose minimum height or lateral distance between the drone and a building(for visual or noise pollution)?

- Yes, current European regulation is too permissive
- No, the city will conform to current and coming European regulation

Question 8: Does the city authority plan to impose curfew for drone operations (night, weekend, early in the morning, late in the evening…)?

- Yes, drone operations are considered as disruptive and the city will do what is necessary to protect the life quality of its population
- No, drone operations represent an important lever of economic development and the city needs to encourage

Question 9: What is city's expectation from the regulators?

1 - No expectation, the regulators will do well anyway

2 - No expectation, the city will do what is necessary to protect and satisfy its population

3 - Expecting to work with regulators to define safe operation which also matches with citizen's expectations

Question 10: Does the city plan to forbid or limit the type of drone usage?

- No, the city cannot intervene
- Yes, because of several nuisances, such as noise, sight on several drones in the sky, etc…

Question 11: May the city impose specific route(s) to drone operations?

- Yes, to reduce drone operations impact (noise, visual) on the population and/or increase the safety
- No, the sky is fully open for drone operation

Question 12: What type of use cases are you planning to deploy in the near future?

- All type : medical purpose, search and rescue, food delivery, passenger transportation, etc…
- Only those dedicated to people care: medical, search and rescue, etc…
- we have no idea

Question 13: What is your timeline for this deployment?

- As soon as possible
- We are not in a hurry
- within 5 years
- within 10 years
- Other

The responder who chose "other" added the following precision: "start with testing in various areas, proceed along the regulation and when the solutions are reaching the commercial level"

Appendix B: Results of the survey on citizens

For questions from 1 to 10, possible answers were:

1 – Not at all

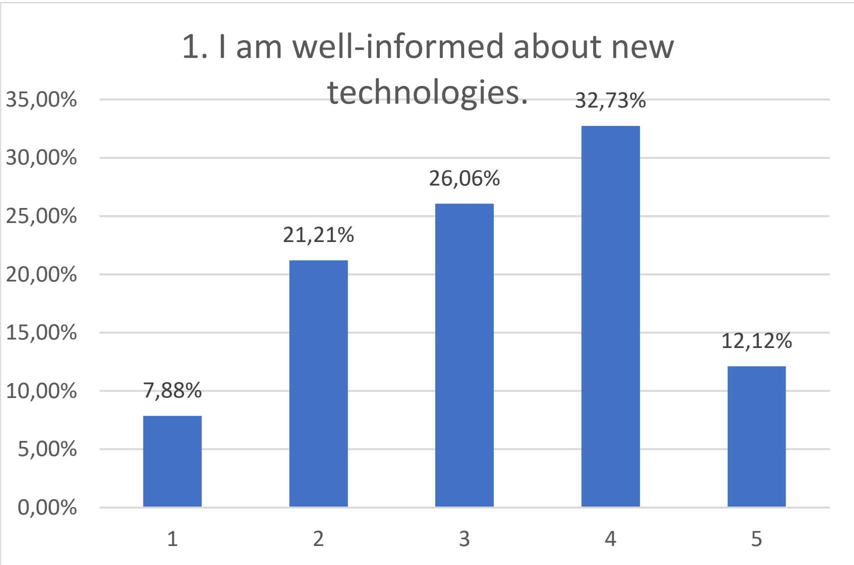
2 – Tend to disagree

3 – Neutral

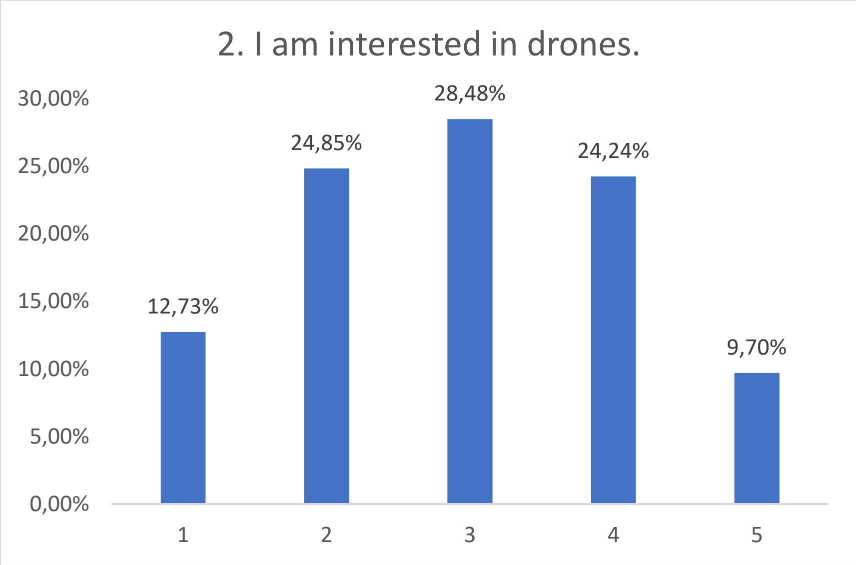
4 – Tend to agree

5 – Totally agree

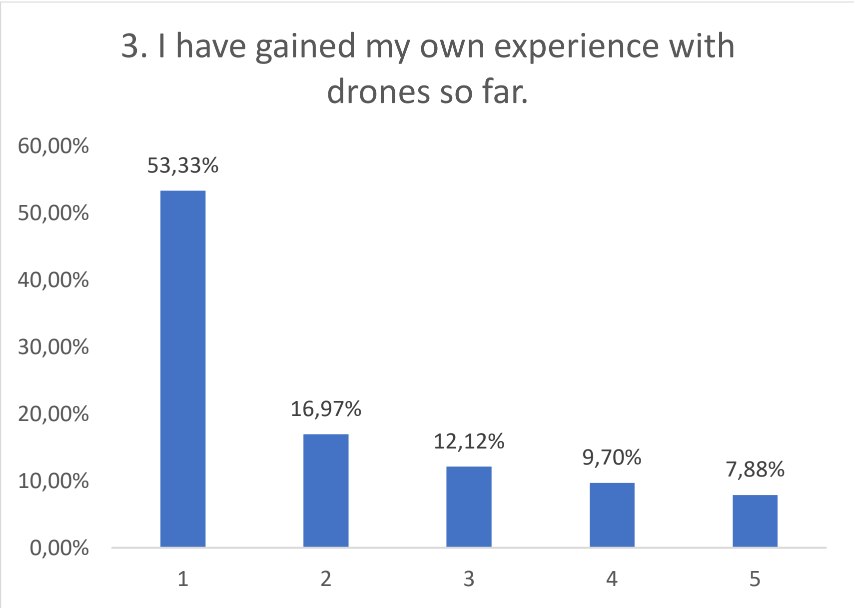
Question 1: I am well informed about new technologies



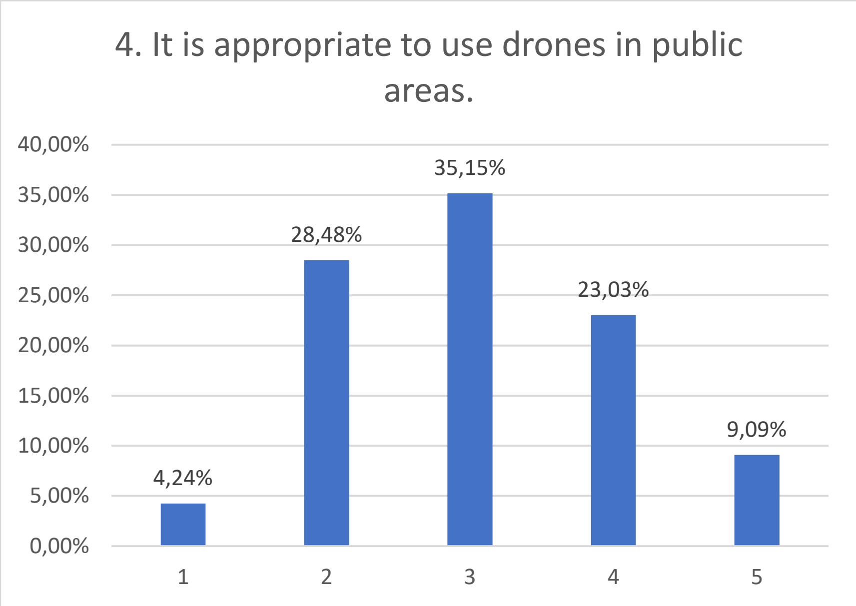
Question 2: I am interested in drones



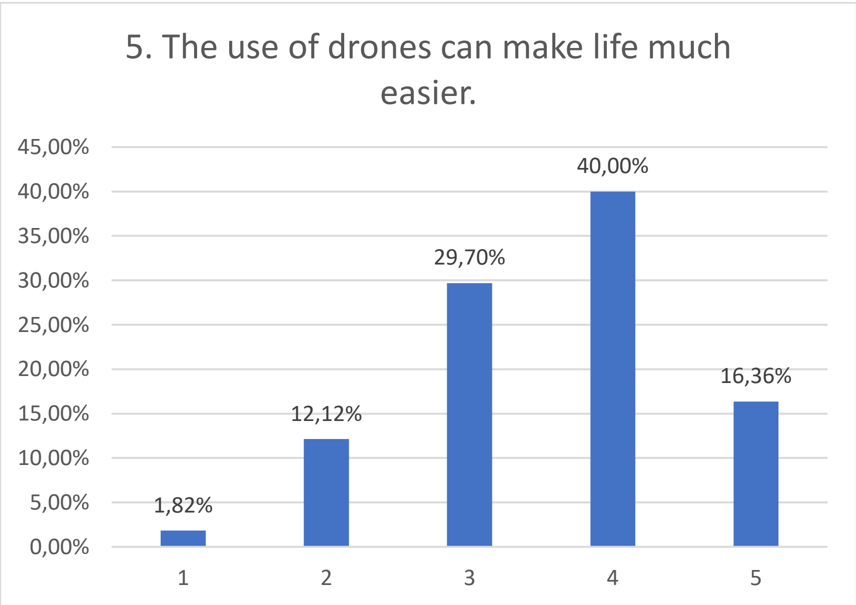
Question 3: I have gained my own experience with drones so far



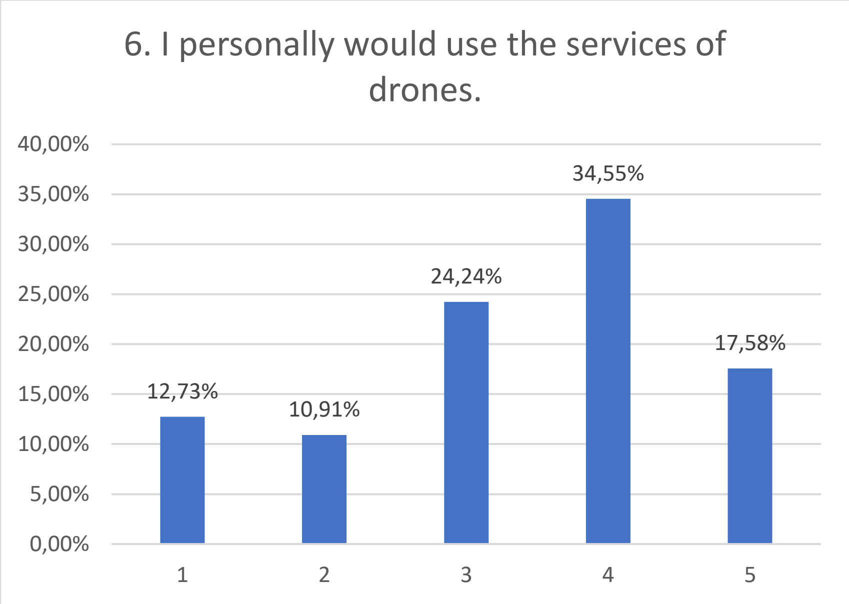
Question 4: It is appropriate to use drones in public areas



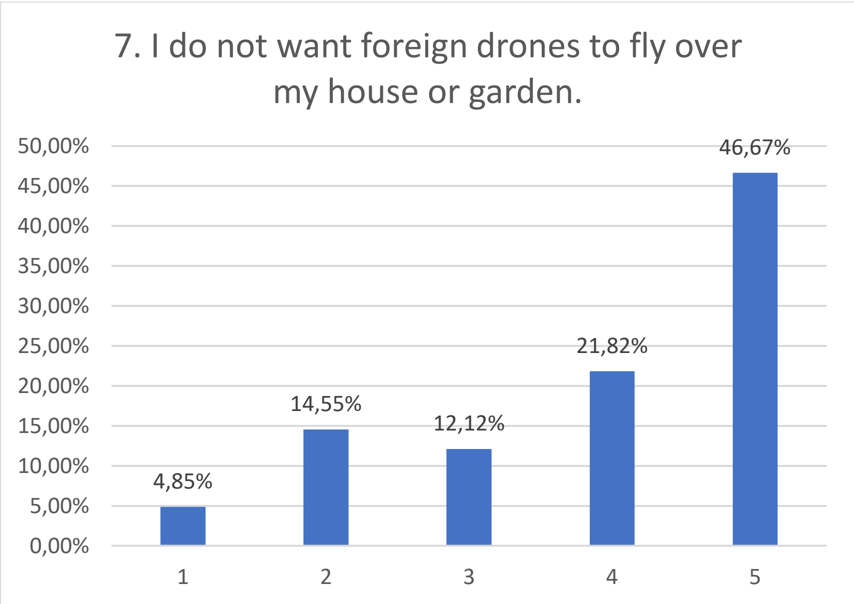
Question 5: The use of drones can make life easier



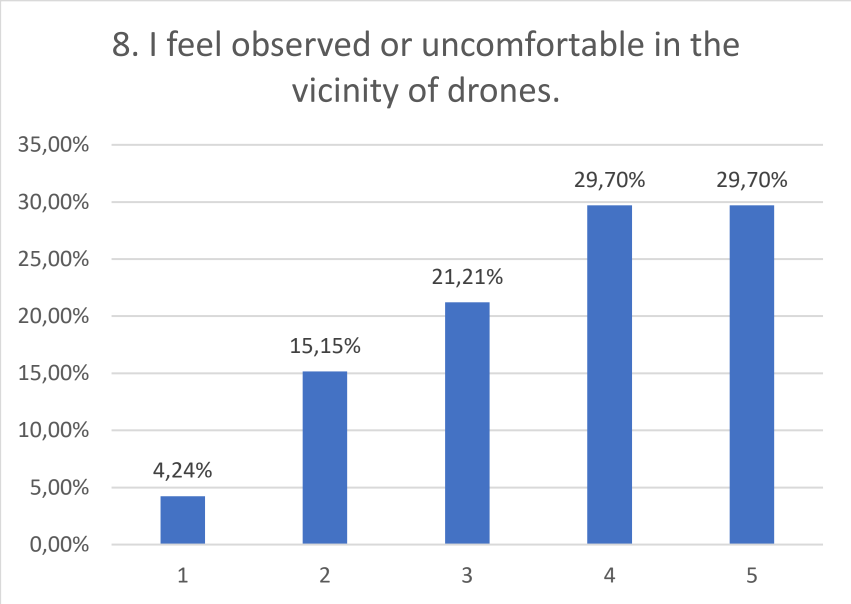
Question 6: I personally would use the services of drones



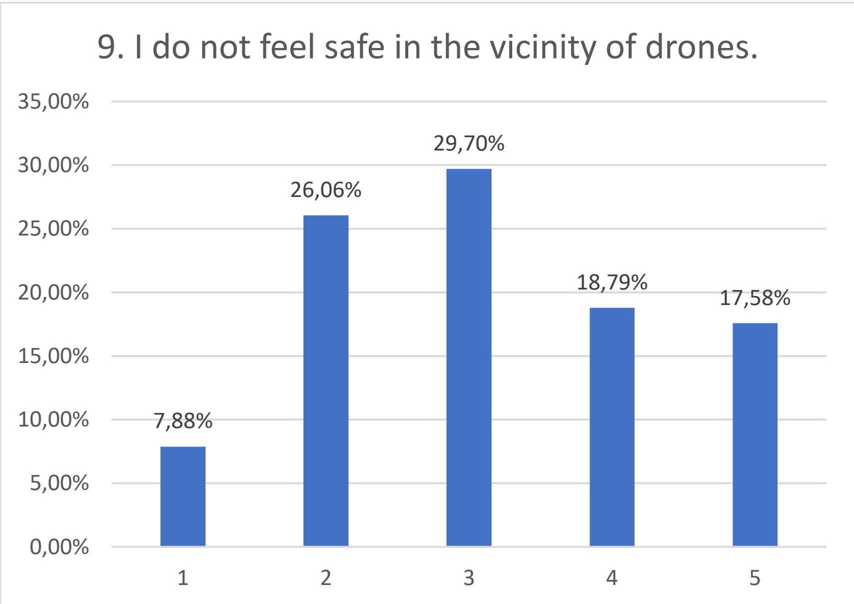
Question 7: I do not want foreign drones to fly over my house or garden



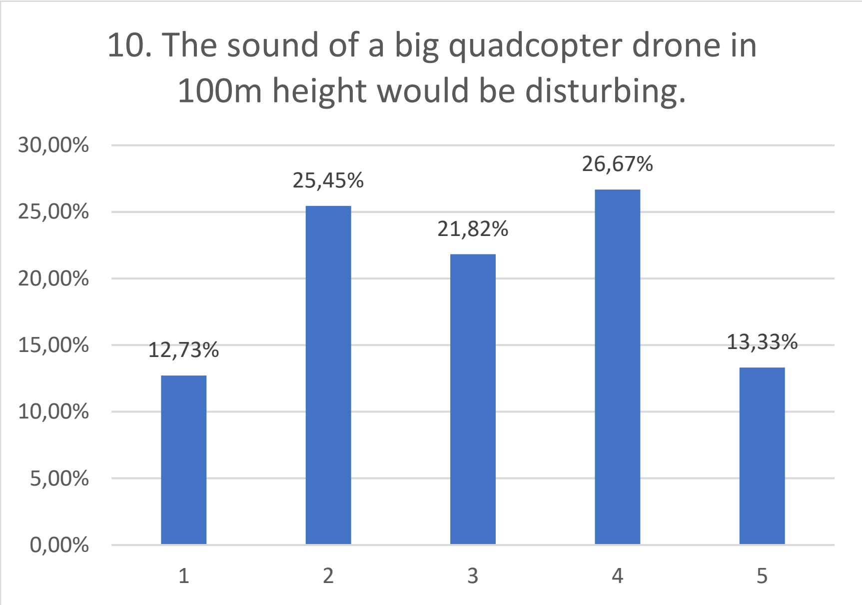
Question 8: I feel observed or uncomfortable in the vicinity of drones



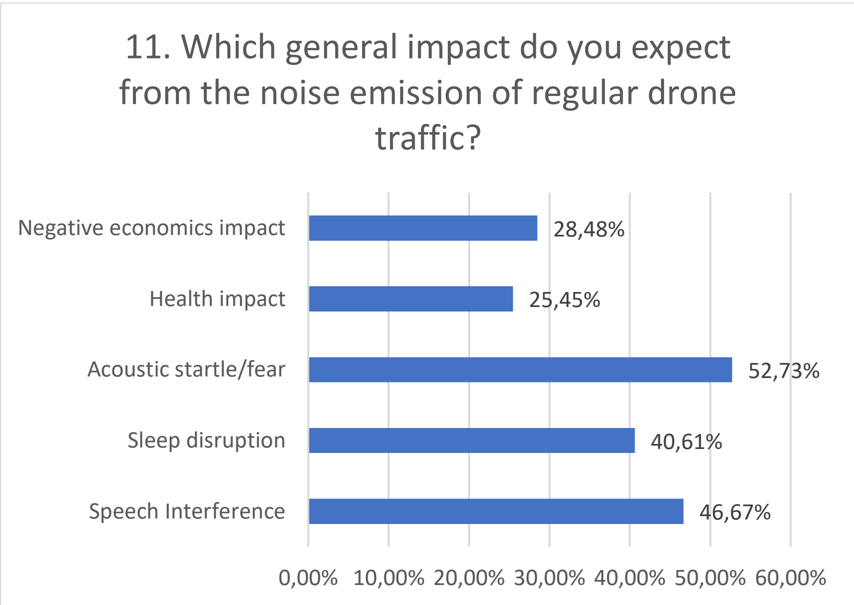
Question 9: I do not feel safe in the vicinity of drones



Question 10: The sound of a big quadcopter drone at 100m height would be disturbing[7]

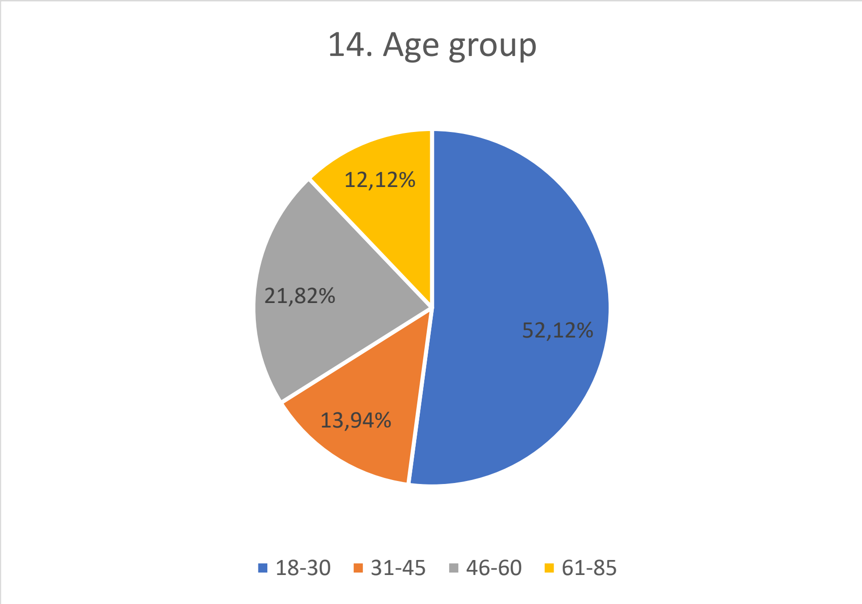


Question 11: Which general impact do you expect from noise emission of regular drone traffic?

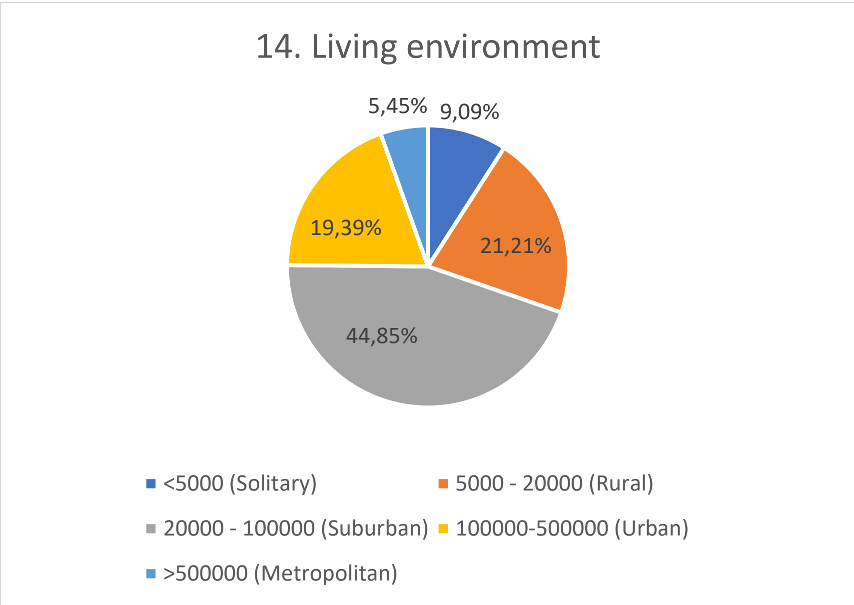


Question 12: Age group of the responder

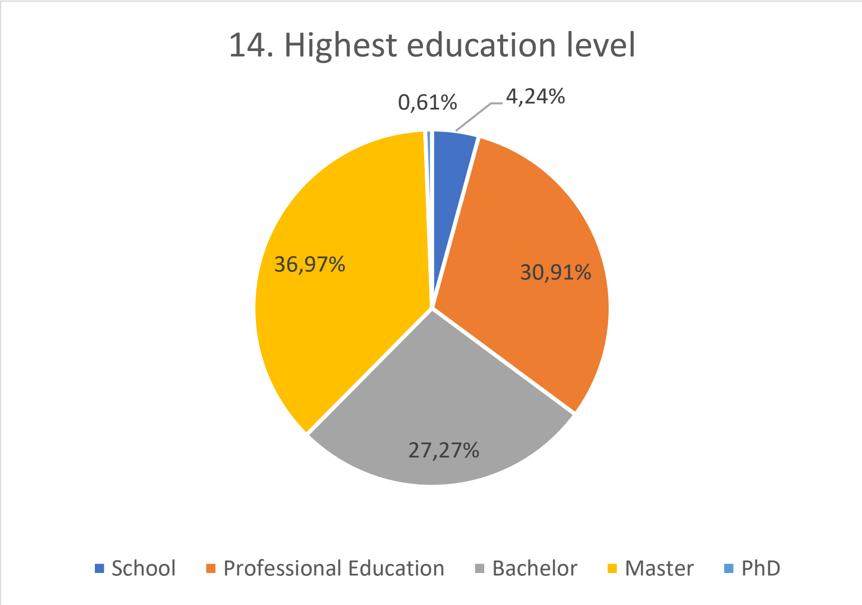
[7] Note of the author: in the French survey, links to two videos were provided so that people have an idea of the sound emission of DJI's Phantom quadcopters like.



Question 13: Living environment



Question 14: Highest education level



Appendix C: City authority involvement in U-space: A realistic perspective/view from Toulouse Metropole

A.1 Identified challenges and proposed approach by Toulouse Metropole

Different challenges identified by Toulouse Metropole to define, develop and deploy the UAM solution.

- What parameters need to be considered while defining the UAM solution?
- How to identify a gap and validate the solution before deployment

Toulouse Metropole is actively working toward improving the quality of life of its citizens and willing to improve and keep monitoring parameters including city pollution, congestion, civil security, fast medical services, equality of transportation between rural, suburban and urban area. The UAM solution provides a hope to Toulouse Metropole to tackle all the problem.

- Toulouse Metropole identified 8 parameters to be considered for developing sustainable deployment UAM solution
    - Technology – All technology partners need to be involved including vehicle manufacturer, traffic management provider, telecommunication company, payload manufacture, etc...
    - Regulation – Interoperable & uniform regulation needs to be defined and local, national & European regulatory bodies need to be involved
    - Policy – Policy needs to define for safe, clean & sustainable implementation of UAM inside an urban environment which will cover noise policy, safety policy, insurance policy, procurement policy, etc...
    - Public Acceptance – Solution needs to be defined for the benefit of citizens which won't be possible without involving them in the decision-making process
    - Inter-modality – Unlike 100 years ago, the urban environment is not free so coordination between ground and air mobility is necessary to manage the traffic network, ensure the citizen safety and efficiently deploy the UAM solution
    - Energy – Energy demand and infrastructure needs to be catered before deploying the electric or hydrogen vehicle or UAM system or system of system
    - Data – Cybersecurity of the whole system and data privacy & management needs to be ensured for the safety and security of the citizens.
    - Infrastructure – Without ground infrastructure including take-off and landing zones & emergency landing pad as well as air infrastructure including telecom network availability, UAM solution deployment is next to impossible

- Toulouse Metropole is developing Francazal multimodality testbed to validate the solution and identify the missing blocks which cover.
    - Drone/Drone Taxi Testing Facilities

- U-Space Testing Facilities
- Infrastructure (ground + air) Testing Facilities
- Autonomous Vehicle (ground + Air) Testing Facilities
- Inter-modality (ground + air) Testing Facilities
- Future Energy System Testing Facilities
- Cyber Security Testing for the complete urban mobility system
- Development of a digital platform to test the MaaS and data management

A.2 Role and responsibility of local authority

By 2030, it is estimated that almost 60% of the world's population will live in urban areas, amplifying the need for innovative and sustainable modes of transportation within and between cities. Urban air mobility (UAM) represents an unprecedented convergence of air and ground transportation systems, utilizing urban airspace and innovative infrastructure. Local Authority needs to play a key role in the development of the UAM sector and bring all the stakeholders to identify and define their role and responsibility for the development of the new sector.

The local authority needs to take the following action:

- Before deployment of UAM solution inside the existing urban mobility ecosystem, cities need to establish a profound analysis to understand the potential benefit of the UAM on future sustainable urban mobility.
- Cities need to promote collaborative working and cooperation among cross-domain stakeholders including mobility, energy, aviation, digital for instance, for the definition of safe, sustainable, green and inter-operable solution which could be integrated inside the existing ecosystem.
- Cities need to include UAM inside existing urban mobility strategy and take an integrated approach to drone operations in the functional city as early as possible. Further, UAM needs to be considered in a holistic view and should complement other modes of transportation which will facilitate UAM integration.
- Cities need to consider the societal need and preference while defining USE Cases and organize an open dialogue between citizens and stakeholder to better understand societal, economical & environmental benefits associated with drone operation.
- Cities need to provide separated and integrated test and demonstration facility for drone operation to define operation attitude, noise level, system safety and security and validation from the citizen.
- Cities need to define a policy to promote drone operations and services which would be beneficial for all section of society instead of privilege one. UAM should be used to improve the connectivity of rural & semi-urban area with the urban area and to improve the efficiency of medical logistics and other essential systems.
- Eventually, before taking the first concrete steps, make sure that there is sufficient support for the envisioned SUMP-UAM within the community/the functional city

Local Authority needs also define sustainable urban air mobility policy which including the following principle:

A.2.1 Plan for sustainable mobility in the 'functional city'

Innovative and alternative mobility solution is needed to solve the problem of congestion, climate change, carbon footprint and others. UAM has shown a potential but the big challenge is to integrate it inside the existing urban mobility ecosystem. The city should deploy UAM solution with a measurable benefit like a decrease in pollution, congestion, rapid medical services, improvement in the security of the citizen. Short term, as well as long term risk including energy load, infrastructure, cybersecurity, accident and others, need to be identified for sustainable deployment of a solution.

A.2.2 Develop a long-term vision and a clear implementation plan

For successful implementation of UAM solution in city framework, it is necessary to include UAM inside city mobility strategy and sustainable urban mobility plan like any other mobility solutions like e-bike etc. Considering the diverse nature of the UAM solution, the city needs to bring all the stakeholders including technology partners (ground + air), regulators (ground + air), policymaker (ground + air) and others on a single table to open dialogue and promote collaborative working approach. A city needs to integrate UAM activity within ongoing or future mobility projects to motivate partners and increase their participation and investment. Lastly, with private partners, the city needs to establish the PPPP model (Private-Public-People- Partnership Model) for sustainable development of future mobility.

A.2.3 Assess current and future performance

The city needs to analyse existing capacity and capability in terms of energy, infrastructure (air & ground), technology, regulation status, ongoing mobility projects, budget and resource. The city needs to identify all the block of value-chain and start investing and developing it along with private partners. Improvement in social, economic and environmental parameters should be the main agenda while deploying UAM solution.

A.2.4 Develop all transport modes in an integrated manner

The city needs to re-define and redesign integrated mobility in view of future mobility demand. For sustainability, MaaS (Mobility as a Service) could be a basis for the development of all-around mobility development including urban air mobility. Social benefit and citizens need to be considered while define UAM solution to be offered by City. Social acceptance and embracement will be key to the sustainability of the UAM solution.

A.2.5 Cooperate across institutional boundaries

UAM development and deployment need cross-domain cooperation and interaction. The city needs to play a vital role in providing a working ecosystem among industry partners, authorities, regulators, research institute and citizens. Additionally, the city needs to guide partners across the domain with urban mobility experience to identify a real need, develop a solution and define regulation. City also needs to support favourable policy and fair playing ground to evolve this new mobility sector.

A.2.6 Involve citizens and relevant stakeholders

The city should put the citizen in the centre of mobility development as well as allocate resource and define a plan to engage citizen in each stage of development. The city with academic institutions and Industry partners needs to organize dedicated workshops and interaction session for benefit of the community and sector.

A.2.7 Arrange for monitoring and evaluation

UAM solution provides a potential to multiple use cases and city needs to define quantitative benefit and measurement mechanism for the same as well as to measure trade-off for deploying UAM solution.

Positive Measurement:

- Improvement of quality of air as compared to earlier
- Reduction in traffic due to drone logistics
- Increase in the number of jobs and city economy
- Improvement in emergency medical response time

Trade-off:

- Increase in noise and visual pollution
- Issue with citizen privacy & security
- Risk of accidents due to a flying vehicle

A.2.8 Assure quality

The city needs to define a policy which covers every aspect of an operation for safe deployment of UAM solution. A city must demonstrate or deploy UAM solution in close collaboration with regulatory authority, national and regional authority, environmentalist and other organizations.

Additionally, other topics where cities need to work on are:

- Data privacy and governance: Data sharing and governance need to be defined and abide by European as well as national laws to protect the privacy and fair sharing of data between different entity
- Fair market competition: Local authorities need to define a policy to provide equal opportunities to all entity
- Equal and correct access to data for USSP: Central information system needs to be deployed by cities with the support of industry partners and regulators to facilitate the data flow among U-Space Service Provider (USSP)