UAM FORESIGHT SCENARIOS

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ASSURED-UAM is a project under the CIVITAS Initiative, one of the flagship programmes helping the European Commission achieve its ambitious mobility and transport goals.

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1 ASSURED-UAM AT A GLANCE

Urban Air Mobility (UAM) services will soon be a reality and more and more deployed in the next decades. Therefore, the ASSURED-UAM project aims to assure outstanding robust safety, sustainability, and acceptability basis for UAM development. To make UAM the first and one of the most effective contributors to climate-neutral urban transport in 2050, the project:

» Identified trends in critical areas.

» Assured broad and comprehensive organisational and policy definition support for authorities, policymakers, and urban industry organisations.

» Accommodated and disseminated aviation best practices, standards, recommendations, and organisational solutions into city administrative and legislative structures.

» Provided recommendations for integrating surface modes under the U-Space Air Traffic Management System.

ASSURED-UAM tested 6 use cases scenarios, built within 5, 10 and 15-year timeframe, in three different regions, at the cities of the Górnośląsko-Zagłębiowska Metropolitan Area (Upper-Silesian region in Poland), Metropolitan City of Bari (Italy) and the Metropolitan City of Porto (Portugal).

2 THE UAM CONTEXT

The straightforward concept of Urban Air Mobility (UAM) is still under definition. Still, the concept is an on-demand and automated passenger or cargo-carrying air transportation service that enables door-to-door (D2D) or near-to-D2D travel transport of people and goods, using manned and unmanned aircraft of diverse configurations within or to densely populated urban areas.

2.1 TRENDS AND FORESIGHT

Large cities need to find faster transportation modes to face the mobility issues in urban, peri-urban, and extra-urban areas fosters the UAM as a solution. Therefore, it is forecasted that the UAM market will have a favourable Compound Annual Growth Rate (CAGR) of more than 10% until 2035. Currently, in the development phase, the market is formed by many countries that already work towards UAM commercial adoption. Additionally, UAM ideas present a good penetration and advance fast in Europe and North America. However, by 2035, the most significant market share (39.27%) will belong to the Asia-Pacific region, and, due to population growth rates and traffic issues, China will lead.

Urban Air Mobility is expected to become a reality in the next 15 years. In 2025, it is expected to introduce goods delivery and initial private mobility service, and in 2035, a more comprehensive development of the commercial passengers' mobility service[1]. However, infrastructures (for boarding, disembarking, take-off and landing, maintenance, battery charging operations, and airports with diverse nodes) and air traffic management still need to be designed, defined, and constructed.

In a D2D mode, vertical transport in urban environments needs to be integrated with the existing cities' surface transportation networks and public services to enable effective and efficient transport of goods and passengers based on regulations, safety, connectivity, and smart operation.

[1] SESAR Joint Undertaking: https://www.sesarju.eu

COVID-19

In the pre-COVID-19 scenario, the still-in-formative-stages UAM, electric Vertical Take-Off and Landing (eVTOL) industry had experienced impressive growth with over USD 1 billion in investments.
The impact of the COVID-19 pandemic on the aviation industry, due to labour and supply chain disruptions and ceased operations, represents losses of more than USD 84 billion, expected for 2020 results. However, the pandemic has also heightened the importance of UAM in critical circumstances. Indeed, some organisations and certain jurisdictions intend to launch commercial passenger operations in the next three to five years.

2.2 ENABLING TECHNOLOGIES

Information and Communication Technologies (ICT) are the main integration means for transport on UAM single mode and multimodal metropolitan transport levels. ICT applications support UAM by implementing the Internet of Things (IoT), Communication Tools, Big Data processing, and the Smart cities concept. The latter aims to mitigate problems by implementing technological progress related to living space optimisation, pollution reduction and energy consumption management.

2.2.1 U-SPACE

U-space provides management services for drones across a set of agreements, protocols, communication, standards, legislation, information, and traffic services to enable an orderly growth of urban air traffic. The U-space services rely on a high level of digitalisation and automation functions and designed specific procedures to ensure safe, efficient, and secure airspace for many drones in an open and competitive market.
The first U-Space implemented a specific set of dedicated services based on geo-awareness, identification, and flight authorisation related to drone movements around airports. According to the increment in drone automation and connectivity, further services and operations are expected to be available in the next years and fully completed by 2035 (Table 1).

Table 1: U-Space Roadmap

U-Space phases	Target	Services
U1	2019	Foundation services covering e-registration, e-identification and geofencing
U2	2022-2025	Initial drone operations management services include flight planning, flight approval, tracking, and interfacing with conventional air traffic control.
U3	2025-2030	Advanced services supporting more complex operations in dense areas, such as assistance for conflict detection and automated detect and avoid functionalities.
U4	2030-2050	Full services, offering very high levels of automation, connectivity, and digitalisation for both the drone and the U-space system

2.2.2 TECHNOLOGIES CONTEXT

Progressive development in aircraft systems, fuel energy sources, propulsion options, and UAM infrastructure is expected in a horizon of 5, 10 and 15 years. The design of aircraft systems for passenger drones focuses on creating a fantastic customer experience, provided by payload, power option, noise pollution, safety, costs, and technical features. Those criteria guide to main concepts of propulsion design: expected time to market, cruise speed, routes acceptance and usage. On the other hand, for cargo drones, a very high level of technological readiness is already available, missing (i) the inclusion of goods delivery in urban civil air traffic (concerning land, take-off, and recharge battery areas) and (ii) unmanned drones' regulation for safe insertion in Air Traffic Management (ATM).

The necessary infrastructure for boarding, disembarking, taking-off and landing, maintenance and battery charging operations are needed to enable urban, peri-urban, and extra-urban air mobility. Vertiports (a sort of small airport) should integrate city reference points, airports, stations, and motorways to provide different nodes to offer an effective D2D service.

Additionally, flexible aircraft transmission systems and advanced control should be developed and integrated with an innovative propulsion platform capable of meeting the ambitious requirements of the new generation of Vertical Take-Off and Landing (VTOL). The development of new advanced battery technologies implemented in innovative hybrid thermal-electric power systems and hydrogen-powered propulsion will permit the shift toward a cleaner and more sustainable energy source. However, for commercial transportation, the electric power source must be safer, more durable, smaller, lighter, and faster in terms of recharge time to enable longer flights.

The timeframe for the features mentioned above is displayed in Table 2:

Table 2: Expectations for the 5, 10, 15 years horizon

Features	2021	2025	2030	2035
Overall framework	-	» No breakthroughs in powertrain technologies. » Manufacturers to seek flight efficiency opportunities in aircraft design.	» Reliable energy source: higher energy density, discharge, and charge energy rates » Long flights operation Efficient, safe, and accessible technologies availability	» Constraints to use hybrid electric aircraft in urban areas due to pollution. » Battery technologies are more efficient and reliable, with more energy-density batteries.
Technology for goods delivery	Ongoing flight tests	On-demand and in the rural area	Urban area test phase	Technology fully available
Infrastructure	Started the build of some vertiport for trial flights	Increase vertiports construction. Initially used by cargo drones and some private air taxis.	Vertiports tested and ready to be in service	Vertiport is entirely in service
ICT	-	» Testing phase of automated drone deliveries. » Unmanned passenger UAM not available in Europe	» Cargo drone operations integrated into supply chain management » Unmanned passenger UAM still not available in Europe	» Fully autonomous, paperless goods supply chain for most loaded route » Not fully integrated autonomous passenger air transport in testing phase in Europe » Fully integrated locally manned public passenger operations

By 2025, a wide range of tests and experiments to evaluate the various technical and business aspects will be made, including new concepts to substantiate the claims and ambitions of personal mobility in competition with existing mobility conceptions.

Once first movers have begun introducing their concepts to the market, the focus will shift toward faster technology development and increased roll-out innovations in a dynamic ecosystem marked by an expanding group of players and a growing number of varying concepts. As a result, in the decade from 2025 to 2035, competition around vertical mobility will heat up.

2.3 AIR REGULATION ISSUES

The regulations of human transporting UAM operations target ensuring occupant and other airspace users' safety, while dangerous goods transportation targets guaranteeing the safety of uninvolved persons, properties on the ground, and other airspace users.

A vast diversity of regulations and standards regulates both transporting types classified as high risk. Protocols and procedures address aircraft, ground station, vertiport, and operation, among other aspects and define a minimum level of safety. On the other hand, medium-risk operations are regulated in an operational-centric modus, built on risk assessments which are pre-defined or done by the applicant and assessed by the competent

authority; as it is a subjective evaluation, the minimum level of safety is not guaranteed.

Regulations for the urban aircraft industry require constant certification for a technology that is still advancing following the rapid and unpredictable pace of UAM market development. Therefore, companies and developer teams must investigate hazards and all impacts of UAM transportation to guarantee the seamless development of certified vehicles. The regulation for VTOL vehicles (electric versions and propulsion configurations included) is presently being formulated due to the relevant infrastructures, and needed technologies are still being conceptualised.

Newly U-Space regulations, published in 2021, defined roles and responsibilities and identified the requirements for operators and Services Providers for Unmanned Aerial System (UAS), operators and U-Space Service Providers (USSP), including procedures of registration services and assistance, accidents and incident reports, and the competent authority of each EU State Member and Manufacturers, and distributors' responsibility.

Additionally, in the governance of urban airspace towards UAM technical and operational advances and further integration in city mobility concepts, the incorporation and recognition of cities and regions as competent authorities is mandatory, identifying their roles and responsibilities.

The integration of UAS in the urban space should account for representatives of development organisations, industry, agencies, and other vital players during the development of standards, thus, covering a wider range of issues. The first introductions of standardised development organisations are expected between 2025 and 2035.

Finally, ATM should change the existing rules, policies, and procedures to cover the operational perspective, welcoming innovative UAM solutions, concepts, and traffic models.

3 AIR SEGMENT AS PART OF URBAN MOBILITY

3.1 STAKEHOLDERS

Cities, industries, small and medium-sized enterprises (SMEs), investors, researchers and other smart city actors are brought together under the European Initiative on Smart Cities and Communities (EIP-SCC), which engages the public, industry, and other interested groups in the development of innovative solutions related to the cities' governance.

However, critical knowledge about citizens' attitudes on mobility deployment is still missing in the strategic long-term planning documents, demonstrated by the current lack of regulation and dedicated infrastructures.

The urban and transport planning actors have been exploited to interact with aviation and ATM actors in the energy infrastructure, financing and procurement fields to elaborate policy and planning recommendations for the future sustainable development of European cities and their transport services compatible with UAM services deployment. The identified actors and stakeholders are shown in Table 3.

Table 3: Actors and Stakeholders and respective fields

Field	Actors and Stakeholders
Urban transport and urban planning	» Transport (including logistics) and infrastructure operators » Smart city services relying on UAM » police and private investors » start-up and innovation local ecosystem » public authorities on environmental protection » Public authorities for social affairs (social cohesion, social inclusion, job security) » educational institutions » Citizens/Civil society
Aviation and ATM	» Airport operators » Vertiport operators » General aviation Operators (recreational and professional) » Commercial aviation Operators » U-space/UTM (Urban Traffic Management) » UAS and UAM operators » UAS pilots » UAS manufacturers » Air Traffic Controller (ATC) » Air navigation service provider (ANSP) » National Aviation Authorities (NAA) » National/regional/local government » Military authorities and Military Operators.
Energy infrastructure	» Grid/smart grid managers » Renewable source energy producers » Fossil energy producers » Energy dealers » Investors » Start-ups » Citizens
Financing and Procuring	» National/regional/local government » Service infrastructure providers » Public and private » investors » Citizens

OPERATIONAL CONSTRAINTS

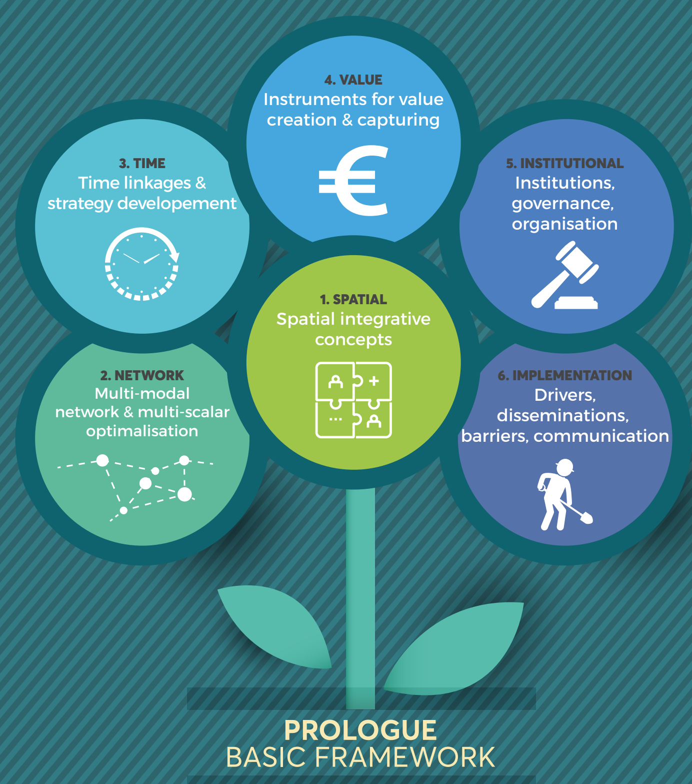
While flight technologies are at a high level of readiness (many are in the certification phase), cities must make investments to adapt existing infrastructures and create new ones to accommodate this new mode of transport. In addition, there are aspects related to regulation, certification, integration of ATM and UTM, environment, and U-Space services that need to be adequately addressed to enable effective implementation of UAM in European cities – managing infrastructure and land use, energy supply, U-space services, ATM Integration, regulations and risk management, environmental aspects, and multimodal transport integration limitations.

3.2 STRATEGIES FOR SUSTAINABLE INTEGRATION IN URBAN AREAS

Under a broader disciplinary dimension (Figure 1), integrating spatial concepts with the respective complementary infrastructures and networks assures seamless mobility integration with all modes of transport. Therefore, to promote integrated physical interfaces, the following solutions are required:

- Examine integrative spatial agglomeration and transport concepts (Transit-Oriented Development or Multimodal corridors).
- Assure a multimodal network optimisation at various spatial scales.
- Change paradigms associated with changing lifestyles and linkages to mobility and accessibility.
- Combine value creation and capture value in combined infrastructure and spatial development.
- Consider the institutional dimension of governance enabling the implementation drivers for integrated planning tackling barriers.

Figure 1: TIILUP framework [2]



[2] Transport Infrastructure Integrated with Land-Use Planning (TIILUP): https://www.nuvit.eu/wp-content/uploads/2018/08/tiilup-scoping-study_dec2013.pdf

4 UAM IN THE NEXT FUTURE

In the short-medium prospect, there is high uncertainty in establishing how the integration might occur. Along with the population density increment, urban areas still need to provide commuting mobility solutions. Therefore, urban air mobility will need to be integrated within cities' network in a vast system perspective, assuring safety and security, public acceptance, relevant regulatory and organisational mobility systems, embedded UAM traffic in a multimodal urban transportation environment, providing infrastructure adaptation, evolution, and integration, also comprising the overall environmental footprint sustainability.

UAM is expected to serve in the specific niche of post-delivery, emergency deliveries, or business trips and would only be considered a mobility-integrated option once technological developments allow affordable prices for the population. Additionally, from the perspective of growing home office working modality, commuting tends to decrease considerably, and UAM will be an enabler of service delivery.

4.1 MOBILITY NEEDS AND EXPECTATIONS AND UAM

Significant needs for UAM are related to suitable locations and buildings for vertiports, similar commercial aircraft safety levels, and low noise levels for better social acceptance.

Currently, the development of vertiports relies upon collaborations between experienced infrastructure players and UAM aircraft manufacturers (although manufacturers have also demonstrated the development of some of their concepts). Vertiports will be easily accessed areas for customers and will be characterised by different sizes and quantities, depending on the expected traffic volumes and the designated city. Power network connection is mandatory for UAM aircraft battery recharge processes.

High safety levels are a vital conditioning aspect of UAM operations. Thus, guaranteeing comparable standards to general aviation safeguards the social acceptance of the new transport concept. Finally, noise generated by the vehicles is a significant risk for UAM deployment acceptance; therefore, during all phases of operation, noise should be kept at an acceptable and appropriate low level.

Positive expectations emerged from the social acceptability of the use of the UAM transport system, as it accounts for improved emergency response time, reduction of traffic jams and local emissions, development of remote areas, creation of new jobs, and market-leading position for Europe, Asia, and the USA.

A complete Concept of Operations (ConOps) definition for cargo drones (detailing Drones landing pad, Cargo drone, Drones Corridor, Drone operations, UTM-specific services, and cargo drones' operations) was produced, as well as a complete passenger's transport application ConOps describes the UAM Operations (Pre-flight, departure, en-route, approach, landing, and post-flight phases).

Both documents are the guidelines for the advance of operations having in joint two statements: the main objective of any changes in the regulatory environments is always to guarantee the safety of the airspace, and UAM services should be flexible and scalable. Next, in the coloured boxes are the background and assumptions of each drone type.

ASSUMPTIONS FOR CARGO DRONES

» It will operate within a regulatory environment whose main regulators are the EU and National regulatory authorities.
» Operational parameters and maintaining oversight are regulated and established by competent authorities.
» Initially, delivery of goods will be covered only in suitable areas (with registered landing pads); alternatively, there will be delivery sorting centres.
» Drones' goods delivery operational information will be on-demand access by the regulatory authorities.
» Cooperative traffic management conducted in compliance with a set of community-developed and regulation authorities-approved Community-Based Rules (CBRs).
» Drone's goods delivery service providers will receive/exchange information during goods delivery operations.
» Drones operators comply with shared intent and are aware of the purpose of other operations in the vicinity.

ASSUMPTIONS FOR PASSENGER DRONES

- UAM vehicles will operate within a regulatory environment where main regulators are the FAA, for the US, and EASA, for the EU.
- The FAA and EASA retain regulatory authority and are responsible for establishing operational parameters and maintaining oversight.
- Operators cannot optimise their operations at the expense of optimising the entire UAM operating environment.
- Cooperative traffic management is conducted in compliance with community-developed and regulation authorities-approved Community-Based Rules (CBRs).
- The regulatory authorities reserve the right to increase individual aircraft operational performance requirements to optimise the capacity utilisation of the airspace structure.
- Operators will receive/exchange information from UAM Providers of Services (PSUs) during UAM operations.
- PSUs will be able to obtain UTM flight information via the UAS Service Supplier (USS) network, and the USS network will be able to get UAM flight information via the PSUs network.
- UAM operators maintain conformance to shared intent, and operators, via PSUs, are aware of the purpose of other operations in the vicinity.
- Regulatory authorities Demand Capacity Balancing (DCB) intervention may be required to support operations as the number of UAM operations increases.

4.2 BASELINE SCENARIO - 2025

The strong interest in this new urban transport system includes airlines and airport management companies severely affected by the global COVID-19 pandemic. The development of vertical take-off aircraft is at an advanced stage, but infrastructures (such as vertiports) and management technologies and regulations are still under development[3]. Therefore, the baseline UAM scenario until 2025 focuses on public transport in urban areas operations conducted with a real pilot on board the vehicle, as follows:

- Goods delivery: automated drone deliveries are expected to be in the testing phase. Therefore, a minimal ability to take full advantage of available ICT solutions is foreseen.
- Passenger transport: unmanned passenger UAM is expected to be not available in Europe.
- Manned passengers' operations over densely populated areas not covered by available ICT solutions due to the relatively marginal scale of operation.

4.3 INTERMEDIATE SCENARIO – 2030

- Goods delivery: Cargo drone operations integrated into supply chain management - all functionalities available (e.g., shipment tracking indicating the real drone position) and increased sustainability optimisation of cargo operators' capacities (carbon footprint reduction).
- Passenger transport: unmanned passenger UAM is expected to be not available in Europe, and manned public passenger operations over densely populated areas will be partially integrated with limited modes in a restricted area.

4.4 FINAL SCENARIO - 2035

- Goods delivery: Fully autonomous, paperless goods supply chain for most loaded routes, automated warehousing, and goods loading/unloading - expected density degree of integration and digitalisation of transport. Populated metropolitan areas require cargo drones to operate solely between dedicated secured ground infrastructure (nodes).
- Passenger transport: Autonomous passenger air transport is expected to be in a testing phase in Europe but still not fully integrated. Unmanned passenger transport (by using UAM technologies) will mature in 2050. Manned public passenger operations over densely populated areas will be fully integrated locally with limited modes in a limited area.

[3] In the first phase, before passing to a full automation of the flight, the operations will be conducted by a on board pilot.

BY 2050

It is reasonable to assume that unmanned passenger transport will mature in 2050 due to the integration aspects emphasised by the feasible identified Use Cases as part of an integrated transport system. Thus, sustainability and social acceptance of this Urban Air Mobility can be facilitated.

Thanks also to the experience gained in the design and construction of ATM systems, solutions for UTM systems will be fully operational in an intermodal journey, relying on new technologies and a high level of automation to manage the growing use of unmanned aircraft efficiently and safely. The critical point for this period will be integration: physical, network, rate (payment methods), information, and Institutional.

The role of technology in the cities of the future will be decisive. Automation, electrification, connectivity and telematic services will simplify the relationship among means, users and the surrounding environment - an innovative rethinking of infrastructures.

5 ASSURED-UAM PILOT CITIES

Cities effectively provide organisational, policy and innovative solutions to overcome the barriers to successfully implementing UAM into older legacy systems and ageing infrastructures. Therefore, three cities across Europe supported the elaboration and evaluation of Use Cases (UC) UAM deployment scenarios:

5.1 GÓRNOŚLĄSKO-ZAGŁĘBIOWSKA METROPOLIA (GZM – POLAND)

Since 2018, the GZM has been working extensively on UAM implementation. Currently, urban airspace is mainly a test area; due to the lack of alternatives for urban transportation, UAM is an option to support urban strategies, health emergency management, risk management and environmental protection. However, the current approach of local governments towards the prospect of a commercially dominated and over regulated urban airspace impacts on diminishing the public acceptance.

GZM metropolitan area understands that UAM is the third dimension of urban mobility and that responsibilities related to aviation regulations will become part of the agenda.

GZM faces challenges in providing transport services in the post-industrial area of strict infrastructural development and high population density in the core of GZM, creating accessibility to such services in rural areas distant from the agglomeration centre and building sustainable urban air mobility for medical applications - including transport and medical monitoring.

5.2 METROPOLITAN CITY OF BARI (MCB – ITALY)

The sustainable mobility plan of MCB focuses on the accessibility and interconnectivity of cities, the reduction of air pollution, and the decrease in energy consumption by constructing a modal interchange terminal next to the Bari Central Station, which should also integrate UAM.

In a short time, MCB will foster the use of drones to support firefighters and civil protection activities and monitor buildings and expects cargo delivery services to solve urban logistics issues downtown and into zones with conditioned access by 2025/2030. In 2030, MCB will also likely offer UAM services for urgent hospital deliveries. By 2035, UAM deployment to transport passengers on demand and deliver goods by drones in multi-trip segments could be a reality.

5.3 METROPOLITAN CITY OF PORTO (MCP – PORTUGAL)

The overall economic context of MCP demands a much broader perspective when looking at the green agenda regarding mobility.

Porto has already implemented policies to promote ground public transport usage, which will not solve, in completion, all mobility issues experienced by the MCP municipalities. Therefore, by exploring the potential of UAM, the MCP expects the following:

- Integration of logistics operators from the airport and the harbour to avoid the increasingly congested roads;
- Delivery of services to less populated municipalities of medicines only available at the main hospital in the North of Portugal (in the city of Port), avoiding the patient flows to the main hospital area;
- Monitoring services in social housing and civil protection actions, using drones to replace human labour; and,
- Improve the Interconnection among all municipalities within the metropolis.

6 ASSURED-UAM USE CASES

The most relevant use case scenarios were defined based on the main UAM cargo and passenger mobility services. The definition of conceptual operations refers to all involved actors, regulations, and procedures (Table 2). The Advanced Air Mobility (AAM) concept emerged by incorporating use cases not specific to operations in urban environments, such as commercial use (inter-city and intra-city), cargo delivery, public services, and private/leisure vehicles. Therefore, the AAM discusses the broadest range of opportunities in passenger and cargo transport in urban and peri-urban areas, indicating the description of VTOL and eVTOL efficiency, safety, and eco-friendly transport of people and goods in the field of logistics in a new size of the urban transport network.

The most probable Use Cases (UC), which are expected to be feasible types of operation within the time horizon, considering the Technology Readiness Level (TRL) and projected regulations. The UCs differ in terms of Payload type, Maximum available flight distance (including return), mission profile, expected U-SPACE level, Flight mode, operation scale, regulatory framework, Operation management, UAS configuration and components, and infrastructure related to the ground, ICT solutions and integration aspects within surface modes of transport. The UCs' deployment aims for each timeframe scenario are shown in Table 4:

Table 4: UC Synthesis

Deployment Aim	2025	2030	2035
Mission Definition	Small Scale of goods up to 30km, man supervised, manual plan, automatic flight	Regular goods, up to 50km, AI supervised, Automatic plan and flight	Small-scale special and regular personal transport of passengers, up to 400km, AI+ supervised, Automatic plan and flight
UAS Specification	VTOL	VTOL	VTOL, ultralight fixed wings
Infrastructure	Public	Public/private	Unprepared public locations

6.1 UC2025|1 – DIRECT LAST-MILE DELIVERY

It is one of first types of drone transport operations commonly considered to be deployed in urban areas. Due to relatively noncomplex mission, it allows to gather first experiences necessary for more sophisticated and real market needs oriented operations (advanced last mile deliveries). Initially, during test implementation, the course of automated operations is expected to be supervised by human operator. Commercially driven simple operation of local delivery of small, light parcels from defined distribution point to final destinations, dedicated to replacing underutilized car and light truck used for courier deliveries.

The covered area is the Downtown/City centre (residential and business functions), densely populated residential areas close to the city centre, and suburban shopping and commerce areas (main area of activity is expected to be focused on less demanding environments related to aerial obstacles, flight conditions, and constraints.
Private logistics services characterise UAM to small companies (big malls in suburban skirts and small business areas in the city centre). Operations will cover the last mile city centre intermodal logistic hub, comprising Parcel lockers on the rooftop of public or private buildings or in a dedicated public space area. The flight termination area is not located in a densely populated space.

6.2 UC2025|2 – POINT-TO-POINT PUBLIC SERVICES

It executes high-priority public service related tasks, in the framework of Private-Public Partnership and led by public entity, enabling burdened by increased business risk operations justified by high public interest (i.e., medical transport of blood, medicines, medical samples, or other light load). Operations directly connect points under public management as hospitals, laboratories, or other entities realizing public services.
The UC provides health care for large hospitals, healthcare campuses and local medical services (pharmacy, medical clinic) sustained by a hospital intermodal logistic hub and a helipad at a local medical service facility located in a low-density populated area for flight termination.

6.3 UC2030|3 – ADVANCED LAST MILE DELIVERY

Last mile deliveries but more complex and with use of heavier carriers able to deliver more than one parcel during single mission. Operations will be fully automatic, however still supervised by human operator, but significantly less human involvement will be necessary allowing a higher number of operations.
Downtown and City centre (residential and business functions) flights, densely populated residential areas close to the city centre and suburban shopping and commerce areas connected to big malls in suburban

skirts and small business areas in the city centre by private logistics services based on a Last mile city centre intermodal logistics hub, parcel lockers spread in the rooftop of public or private buildings, or in a dedicated open public space. The flight termination area is not located in a densely populated space.

6.4 UC2030|4 – POINT-TO-EVERYWHERE PUBLIC

The high public interest on high-priority public service related tasks (complex and demanding higher risk such as medical transport of first-aid equipment blood, medicines, medical samples, or other light load can be given directly to or from the accident site, enables more risky operations, which are dedicated to directly connect points under public management as hospitals, laboratories or other entities.

Covers Large hospital campuses and any areas in served zones of the city offering healthcare, public safety, and emergency management based on a hospital multimodal logistic hub and any available space on the ground or elevated buildings (if it matches minimum safety requirements for take-off and landing) in a low densely populated area (for flight termination).

6.5 UC 2035|5 – DIRECT MEDICAL TRANSPORT OF PEOPLE

Direct test operations initially are supervised by human operator within single metropolitan area, enabling the unmanned medical transport between hospitals of qualified passengers/patients, that will not require medical assistance during flight, providing healthcare services between large hospital campuses using hospital heliports for flight take-off and termination

UC is projected to allow gathering necessary experiences for more complex and commercial unmanned passenger transport operations to gradually replace traditional helicopter emergency medical service services.

6.6 UC2035|6 – AUTOMATIC PERSONAL AERIAL TRANSPORT

Considering the 2035 certified and in-the-market aircraft concepts, air vehicles reach densely populated areas sharing airspace with unmanned traffic. Optionally manned are allowed to enter U-SPACE area only in automatic flight mode (autopilot active), introducing the fully autonomous passenger operations of the future. However, it is still not achievable fully pilotless operations. Operations, initially assisted by human pilot in the aircraft, will be allowed to take-off and land in mixed traffic airports/vertiports in automatic way, Based on a multimodal transport hub which includes heliports close to the railway station, ports, and airport, connected to the urban road, rail and water transport to deliver events and tourism passengers to the destination heliport.

6.7 ENVIRONMENTAL COST AND ENERGY ESTIMATION FOR ASSURED-UAM USE CASES

A complete life cycle cost and energy efficiency for each UC were calculated considering a monetised environmental footprint component by identifying sources and assuming values for investment, energy, operational, delay, deadhead, environmental and end-of-life costs. The obtained results of eLCC (environmental Life Cycle Cost) analyses for all use cases delivered crucial information about the areas that should be considered by decision-makers as well as UAM providers and operators in terms of costs Key Performances indicators (KPI) according to climate neutrality, sustainability, efficiency, and social aspect-related criteria.

Increasing awareness of external costs generated by transport driven by the European Commission's Green Deal strategy can be undoubtedly identified as one of the key justifications for such an approach. Indeed, it would enable comparison, giving an accurate environmental-oriented picture of the urban and peri-urban transport costs, and set a base for a future, fully integrated, prioritised high-level, sustainable, and climate-neutral system with a decisive role of UAM.

Assuming a favourable economic situation, other costs – driven by airspace accessibility, unsatisfactory level of ATM integration, burdensome certification process, slow or (lack of) progress of powertrain options, breaches in cyber security, low (or zero) degree of automation –

could diminish affordability. Moreover, even if taxpayers finally believe UAM is safe and affordable, some groups often block any improvements (or activity) in their local environment. These so-called NIMBYs - Not In My Backyard - could make the costs of the UAM infrastructure development (or improvements) and UAM operations rise rapidly beyond a reasonable level.

Regardless of operation type – passenger or cargo – the general rule that the "greater the demand, the lower the unitary costs" also applies to UAM services.

Undoubtedly, the most significant financial contribution to the UAM operations must be made at the initial stage when all the infrastructure and aircraft must be purchased. This cost ranges from 3.5M EUR for small cargo transportation to 12M EUR for passenger transportation.

In the operational phase of UAM, in which energy, operations, delay and deadhead, environmental and end-of-life costs can be distinguished, the operating expenses account for nearly 99% of all identified costs. Putting it in numbers, this cost category ranges from 471,000 EUR/year for small cargo transportation up to almost 2.5M EUR/year for passenger transportation. The dominant subcategories in small/medium cargo flights are flight costs, general administrative expenses, and depreciation costs. In contrast, in passenger and big cargo flights, the increased impact of fees is associated with flying and passenger services costs (for cargo flights, it is loading/unloading parcels).

Energy costs vary from 300 EUR/year to 26k EUR/year. It is worth remembering that most of this cost is related to the aircraft's energy consumption during flight, while the rest is used by ground infrastructure. Moreover, the energy cost is strongly correlated with the distance travelled and the aircraft size—the longer the flight and the bigger the plane, the higher the energy cost.

Another cost source for UAM providers and operators is the delays. These can cause up to 45,000 EUR/year of refunds for parcel recipients and up to 900 EUR/year for UAM passengers. Depending on the size of an aircraft and the distance travelled in a single operation, the total environmental costs can vary between 1,000 EUR/year for small cargo transportation and up to 8,000 EUR/year for passenger transportation. The carbon emission charges are the most significant contributor to these costs. However, the end-of-life (recycling) cost in the context of other expenses is relatively low. The yearly cost varies between 128 EUR/year to 564 EUR/year, correlated with the number of available aircraft and their lifetime.

When considering the profitability of UAM operations, the deadhead ratio is information of significant value for all UAM providers around passenger transportation. Due to the repositioning of aircraft required in case of their unavailability at a given vertiport, the assumed 20% of all operations may not be monetised, thus lowering the net profit of UAM providers.

7 UAM SERVICES IMPLEMENTATION CHALLENGES IN EUROPE

UAM requires the ability to control and synchronise the activities of logistics, by deploying flying vehicles and developing an entire ecosystem surrounding it: passengers, aircraft, and support systems within a highly complex multimodal transport environment.

The growth of shared mobility, on-demand services and pay-per-use models in recent years have questioned the traditional technology envisaged. In addition, the abundance of new data on mobility preferences and pricing will further enable mobility service providers to anticipate demand for UAM, prioritise the most attractive corridors, manage network efficiency, and integrate different transport modes.

At the same time, infrastructure is a crucial constraint for UAM. It is critical to transforming last-mile logistics and people mobility, improving environmental sustainability, traffic congestion and the efficiency of the whole urban activity.

7.1 STAKEHOLDERS' GOALS AND EXPECTATIONS

Collaboration between different stakeholders (e.g., incumbents, start-ups, public bodies, or research organisations) is crucial to capture the social benefits of UAM for the broader public and its viability from a business perspective. There is a great role for infrastructure providers and operators, real estate companies, transport hub operators and retailers in building the foundation of the future UAM landscape. These players have a crucial role to play in the future of urban mobility, From re-planning urban areas, repurposing current buildings or constructing UAM infrastructure from scratch perspectives.

The inclusion of "active agents" stakeholders helps to field and share needs and requirements that legitimise paths and decisions, bringing issues that merit investigation to the surface. Therefore, the ASSURED UAM Extended Advisory Board (EAB) of experts was consulted through surveys, interviews, and workshops. The surveys aimed to Gather preliminary impressions and feelings on

possible UAM foresight, not biased by the presentation of ASSURED- UAM use cases. The interviews addressed Financing and Public Acceptance, Operational Constraints, and validation of LCC System Components themes to derive an explanation of web-survey results. Lastly, during the workshop, the pros, cons, gaps, and suggestions of proposed Use Cases were discussed.

The EAB was divided into the three above-cited thematic groups, varied and extensive, covering all types of organisations potentially entangled by UAM deployment:

» Manufacturing and maintenance Industry
» Infrastructures Industry
» UAM/Air business operator Industry
» Research organisation
» Public institutions, networks and citizen associations involved in strategy, policy, and rulemaking.

The 83 EAB members (41 for the "Strategy, financing and public acceptance" Thematic group, 26 members in the "Operational constraints", and 16 members in "System Components LCC ") represent the 15 EU Member States, the United States (Ohio University), Israel (city of Yerouam), and 5 European (supranational level) bodies and networks.

7.2 eLCC UAM STAKEHOLDERS' ANALYSIS

From a city planning perspective, the implementation of UAM necessitates physically designed and utilised spaces that provide digital services and electricity for energy demands. Therefore, dialogue and collaboration between jurisdictional and transportation entities, city planning authorities, community bodies, NGOs and private sector players are key for developing a coherent policy around UAM.

Regulators need to define a framework where innovation is not stifled while the critical concerns of passenger safety and privacy are addressed. Regulation for the entire UAM ecosystem must be designed to make "flying cars" a reality. Besides a robust framework governing the safety requirements associated with increased air traffic, regulations surrounding UAM vehicle design, sustainability, interoperability, security, and data privacy must be harmonised over the coming years. Secondary regulation on reducing noise pollution and preventive operational measures is also crucial to the scale at which UAM is deployed in cities.

Further vital factors are the social acceptance of UAM passengers and the economic propensity to pay for such services. Acceptance of, and trust in, autonomous technology and its corresponding safety systems will support the widespread deployment of UAM solutions. On a community level, pre-conceptions that autonomous technology will render jobs obsolete could pose a barrier. Environmental issues, mainly concerns about noise pollution and city aesthetics, could also lead to resistance to eVTOL acceptance.

From an economic perspective, the price per trip offered by operating companies and the opportunity costs associated with that price would be a major deciding factor on the scale at which UAM services are adopted.

7.3 UAM AS PART OF A MULTIMODAL TRANSPORTATION SYSTEM AND FUTURE OPPORTUNITIES

Transport integration is an organisational process through which the transport system's planning and delivery elements are brought together across modes, sectors, operators, and institutions to increase the net environmental and societal benefits. The main imperatives for integrated transport system development are a physical interface between modes, operational integration between modes, service integration - common fare, ticketing system, etc.

Although the integration of physical infrastructures

contributes to seamless mobility, it does not assure by itself its implementation. Only with an operational integration between modes such an objective can be achieved.

The integration of the vertical transport segment with traditional mobility systems in urban and peri-urban environments has not been broadly implemented to the overall extent of the mobility concept, which makes it challenging to extrapolate assumptions or conclusions about the few existing examples worldwide.

The integration of the service is even more challenging. For example, when the UAM is used to connect peripheral areas that are not easily accessible by other means (e.g., Norway), in such conditions, the operation of the service must be financed as the service must be equivalent to public transport.

The integration of the Urban Air Mobility within the ground mobility scope, although an emergent trend, is still entirely dependent on factors such as the age of the population, changes in national strategies that promote deployment among commuters, population welfare and safety issues.

7.4 SOCIAL ACCEPTANCE

Social acceptance is closely related to the perceived benefits and impacts on the quality of life, health, social and economic well-being and was approached in a co-creative process that involved different stakeholders' perspectives.

Many barriers must be overcome to attain wide societal approval of UAM vehicles. Concerns about public nuisance and environmental pollution, restrictions in use, privacy, safety, security, capability, economic, and regulatory factors must be considered. Privacy concerns are connected to drones being equipped with live video cameras, which could be used to spy and collect personal information. Safety concerns arise from the possibility of malfunctioning, causing accidents, damage or harm to people, other aircraft, or buildings.

Safety also deals with the safe delivery of packages in delivery scenarios commonly associated with criminal activities like hacking and hijacking drones or using them to aid in crimes. Secure communication links and data platforms are essential to ensure that only authorised persons can access sensitive data. In contrast, geofencing technology ensures that drones only fly within the airspace they can enter.

Innovative solutions must address these challenges to increase the reliability and availability of functionalities and functional safety and reduce costs and energy consumption.

The industry tries to establish the most probable deployment strategy, limited or constrained, by what will be verified by the public acceptance of cities and citizens.

From the cities' perspective, there is a considerable challenge to integrate UAM with the environmental goes established by the European Union. Furthermore, cities must incorporate a new functioning layer in a scarce and valued suitably: public spaces.

All these activities will be shaped by public perception of the new mode of transportation and respective infrastructure and systems. However, at this point, the main stakeholders' perceptions and interests are difficult to integrate (regarding the relevant uncertainty about the topic).

UAM deployment can evolve in specific niches for which public acceptance might be positive, such as using drones or/and aircraft for emergency services. However, other more frequent uses with a lower perceived benefit of public good, such as app delivery services, drones or/ and aircraft, are expected to receive higher opposition. Moreover, the larger and heavier the device, the less likely it will be accepted due to the expected noise, visual intrusion and, above all, the perception of safety.

For now, neither industry nor cities foresee a strategy to internalise the costs of those externalities imposed on society. Lastly, and still with a significant level of uncertainty, there is the factor of service affordability. In the case of lower-value cargo, it is still unclear whether to move it by air or how much customers would be willing to pay for such a system. In the case of "air-taxi", passenger transport, it is expected that public acceptance towards such a mode will be harder to achieve.

7.5 AFFORDABILITY LEVEL

A significant level of uncertainty still surrounds the affordability topic at UAM. Therefore, affordability can be approached from different perspectives, depending on the business model adopted for the UAM deployment and the city's aerial movements policy.

In the short term, parcel deliveries are expectable with a low level of implementation within the urban areas. The industry can support the initial investment in UAM under a market penetration strategy and not necessarily as a lucrative business with a large profit margin.

In the medium and long term, when the level of operations is expected to increase and the respective processes to become more complex, it is mandatory to link the chosen business model to public acceptance and cities' development plans.

Whether cities have a perspective towards UAM as a cleaner transport option, public subsidies could help the business model. However, the expectations regarding the recent environmental limitation impositions on ground transport vehicles and the strong movements from citizens oppose any solution that causes noise and visual nuisance. Therefore, the possibility of subsidising UAM seems complex and not probable, except in specific niches such as health-related transport and connections from remote highlands and similar areas.

The emergence of autonomous vehicles on road transport, particularly in ridesharing, is expected to make the UAM affordability issue more complex. Autonomous vehicles will help to decrease the operational costs of ground mobility alternatives. This will become a reality in the short term, and the competitiveness of UAM with such an option will be challenging to be appealing.

The uncertainty surrounding the business models has consequences on the relevance of the affordability topic. Initially, affordability can play a relevant role in user decision-making to specific niches such as airport shuttles. On the other hand, affordability might not be crucial for users to make this option on the luxury air-taxi or intercity movements. Thus, the UAM option will probably be expected as an option that exists and is available for those who can afford it. The actions and characteristics of the operations demand will influence the public acceptance towards these solutions.

7.6 FINANCING INSTRUMENTS

Due to the high cost of pilot and demonstration work, only a limited budget could be allocated to the trial implementation of changes or test services, which constituted a restriction on the exploitation of the potential of such actions. The perception is shared by Bari and Porto metropolitan cities, which are receptive to urban air mobility and have recently joined the UAM Initiative Cities Community (UIC2) of the EIP-SCC. Nevertheless, the cities faced funding restrictions for conducting pilots and awareness workshops seeking higher social acceptance.

The cities monitor European funding programs to understand how to introduce the new air mobility concept into the city. Until the fall of 2021, Urban Air Mobility (UAM) was explicitly mentioned in the HORIZON-CL5–2022-D5–01–13 Research and Innovation Actions (RIA) topic: the Digital aviation technologies for new business models, services, emerging global threats and industrial competitiveness (HORIZON-CL5–2022-D5–01–13), could contribute to transforming digital aviation technologies that will enable new European business

models and products with minimal environmental impact and competitiveness; transforming digital aviation, space technologies, and UAS.

In the Horizon Europe programs, there is a lack of opportunities for a new and innovative form of mobility as UAM; i.e., the call (Clean and competitive solutions for all transport modes (HORIZON-CL5–2022- D5–01)), the air mobility appears competing with other mobility/transport modes. Additionally, new projects are expected to provide a technological readiness level of 7–8, meaning that technology should be tested, "flight qualified", and ready for implementation into an existing technology or technology system. This implies the research proposal should be built using a still-under-development platform for UAM.

8 ASSURED-UAM ACQUIRED KNOWLEDGE IN PILOT CITIES

During the tests in the Pilot cities, it was possible to understand the local impacts of UAM deployment. As a result, cities are aware of their role in enabling UAM services following the needs and preferences of their citizens. Urban stakeholders see their role as co-creators of services but also really influence the scope and location of UAM/U-space operations. This influence should also apply to decisions on the necessary infrastructure and instruments to mitigate risks and adverse actions.

Public involvement, engagement and participation were the highlighted topics for the deployment of UAM. The issues are related to the choice of carrying out the initiative in a densely populated urban district, which caused management difficulties, solved by creating a Ground Controlled Area to ensure the safety of the flight operations in MCB. Public involvement and acceptance were cited as critical issues in UAM-related projects in MCP, which stated that without enough public involvement and acceptance, any socially beneficial UAM plan might fail. Indeed, the capabilities, and innovative services UAM solutions, demonstrated in the real world to a broad audience, made it possible to capture the great interest of participants and the general citizens. Citizen and stakeholder involvement at every planning and implementation stage of urban mobility is also highlighted in the GZM, whose pilot case focused on

medical care transport.

Therefore, the following general conclusions were reached from the cities' pilots:

- Engage local authorities, cities experts, end-users, and clients – in the process of developing important public services according to their needs;
- Cooperate with local, central, and international stakeholders across the UAM ecosystem, including the public and private sectors, on the legal and technological frameworks;
- Engage in pilotages and demonstrations;
- Communicate simply and visibly to increase the acceptance and comfort level of residents;
- Initiate and coordinate public debate in which the potential benefits and challenges of UAM are discussed in an unbiased and transparent way;
- Co-create simulation, with a focus on use cases that serve the public good with different stakeholder groups in various forms;
- Provide experiences of drones, air taxis and their characteristics (UAM services pilots in living labs') to the public;
- Maintain permanent cooperation among the different authorities to frame how UAM will be integrated with mobility and urban planning;
- Benefit from the knowledge provided by cities in projects where the municipalities play an active role.

9 SUPPORT RESOURCES

This document was built based on the published results of the ASSURED-UAM Acceptance, Safety and Sustainability Recommendations for Efficient Deployment of UAM Project (H2020 GA No 101006696). For more information, consult https://assured-uam.eu/public-deliverables/. Specific technical details can be found on the dedicated reports[4]:

D1.1	Technology Readiness Review Report
D1.2	Regulatory Framework Report
D1.3	Urban Mobility Integration Strategies Report
D1.5	Final ConOps Definition
D2.1	UAM Deployment Strategy Report
D2.2	Operational Constraints Report
D2.3	UAM eLCC+E estimation Report
D2.4	Financing and public acceptance
D2.5	Opening scenarios for UAM in the future integrated urban mobility system
D2.6	Final scenarios for UAM in the future integrated urban mobility system
D3.1	Stakeholders' engagement plan
D3.2	Stakeholders consultations report
D4.1	Standards and recommendations for UAM components
D4.2	Policy and urban planning standards and recommendations
D5.1	GZM Metropolis UAM case
D5.2	Bari Metropolis UAM case
D5.3	Porto Metropolis area UAM case
D5.4	Implementation process conclusions and observations

10 ACRONYMS

AAM	Advanced Air Mobility
ANSP	Air navigation service provider
ATC	Air Traffic Controller
ATM	Air Traffic Management
CAGR	Compound Annual Growth Rate
CBRs	Community-Based Rules
D2D	Door-to-Door
DCB	Regulatory authorities Demand Capacity Balancing
EASA	European Union Aviation Safety Agency
EIP-SCC	European Initiative on Smart Cities and Communities
eLCC	Environmental Life Cycle Cost
eVTOL	electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration USA
GZM	Górnośląsko-Zagłębiowska Metropolia – Poland
ICT	Information and Communication Technologies
IoT	Internet of Things
KPI	Key Performances Indicators
MCB	Metropolitan City of Bari – Italy
MCP	Metropolitan City of Porto – Portugal
NAA	National Aviation authorities
PSUs	Providers of Services
SMEs	Small and medium-sized enterprises
TRL	Technology Readiness Level
UAM	Urban Air Mobility
UAS	Unmanned Aerial System
UC	Use Cases
UIC2	UAM Initiative Cities Community
USS	UAS Service Supplier
USSP	U-space Service Providers
UTM	Urban Traffic Management

[4] The confidential Deliverables are not present in the list.

ASSURED-UAM CONSORTIUM

Łukasiewicz Research Network – Institute of Aviation, Ł-ILOT, Poland,
www.ilot.lukasiewicz.gov.pl

Centro Italiano Ricerche Aerospaziali, CIRA, Italy,
www.cira.it

Centre of Engineering and Product Development, CEiiA, Portugal,
www.ceiia.com

Institute for Sustainable Society and Innovation, ISSNOVA, Italy,
www.issnova.eu

Distretto Tecnologico Areospaziale, DTA, Italy,
www.dtascarl.org

Górnośląsko-Zagłębiowska Metropolia, GZM, Poland,
www.metropoliagzm.pl

Nederlands Lucht- en Ruimtevaartcentrum, NLR, The Netherlands,
www.nlr.nl

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