Integrating Urban Air Mobility into smart cities: a proposal for relevant use cases in the next decades

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Abstract. Urban Air Mobility development and deployment into future cities is gaining increasing and relevant interest in the last years, as a new mobility form suitable to meet the future greener, scalable and efficient mobility targets needed to solve the issues today's big cities are facing in terms of traffic congestion as well as related environmental consequences. In this framework, the ASSURED UAM (Acceptance, Safety and Sustainability Recommendations for Efficient Deployment of UAM) project has been funded by H2020 and has been concluded in the year 2023, with the main objective, successfully reached, of providing cities with knowledge concerning deployment of UAM services and definition of necessary standards and recommendations assuring common acceptance, safety and sustainability within integrated metropolitan transport system for three time horizons (2025, 2030 and 2035). In the project, dedicated activities have been carried out to develop suitable operational concepts for Urban Air Mobility (UAM) deployment in the next decades. After that, in the project dedicated activities were carried out to further refine and design the most relevant use cases for UAM deployment in the next decades, leading to the public issue of dedicated overall document. This paper aims providing final outline of the ASSURED UAM designed use cases, starting from the analysis of overall identified possible UAM applications and, then, specifically focusing on the description of the six main use cases considered as relevant for the application under the wider societal benefits point of view. In the paper, such main use cases are described and their specificities in terms of expected operational environment, needed technological enablers, envisaged regulatory implications, and so on, are reported and commented.

1. Introduction

Urban Air Mobility (UAM) will represent additional alternative for transport into future big cities over the next decades, allowing for accommodation of always increasing requirements and constraints that environmental pollution issues, due to always increasing traffic congestions and related emissions, are imposing. Many research and development activities are and have been devoted to this topic and, in this framework, the ASSURED UAM (Acceptance, Safety and Sustainability Recommendations for Efficient Deployment of UAM) project [1] has been funded by the European Commission Horizon 2020 programme. The project was successfully concluded in the year 2023, providing cities with knowledge

concerning deployment of UAM services and definition of necessary standards and recommendations assuring common acceptance, safety and sustainability within integrated metropolitan transport system for the three time horizons (2025, 2030 and 2035) addressed in the studies.
The project study logic encompassed first the development of the Concept of Operations (ConOps) for Urban Air Mobility (UAM) deployment in the next decades, as reported in dedicated reference papers. Such studies and related issued ConOps led to: 1) the identification of the most relevant and promising technologies that can enable the UAM implementation over the next decades [2]; 2) the outline of the regulatory framework in which the UAM will be shaped [3]; 3) the outline of the most relevant aspects and constraints affecting the UAM deployment [4]-[5]; 4) the outline of the foreseen UAM concept of operations and of the most relevant use case that are expected to be implemented in the cities over the three considered time horizons [4]-[5].
Based on that, further refinement and detailed design the most relevant use cases for UAM deployment in the next decades has been carried out. It is worth emphasizing that the definition of the Use Cases properly considered also the aspects related to future multimodal transport alternatives availability and, to this aim, the activities were conducted in parallel and in cooperation with the SESAR JU funded project X-TEAM D2D (Extended Air Traffic Management for Door-to-Door travel). The cooperation led to useful and very productive cross-fertilization when addressing the UAM integration into overall multimodal transport network related aspects, as discussed in the reference papers from [7] to [12].
This further paper adds to the foundation established by the earlier works that have been following the development of the ASSURED UAM project activities execution. It is specifically aimed to outline the ASSURED UAM designed use cases, starting from the analysis of overall identified possible UAM applications (section 2) and, then, specifically focusing on the description of the six main use cases considered as relevant for the application under the wider societal benefits point of view (section 3). In the paper, such main use cases are described and their specificities in terms of expected operational environment, needed technological enablers, envisaged regulatory implications, and so on, are also reported and commented.
The complete collection of the project's reported outcomes that are applicable to the topics addressed in this report is made publicly accessible through the deliverables listed in the references from [13] to [17], which can be downloaded from the project website [18], where the full set of the project produced deliverables is available.

2. UAM Concept of Operations definition studies and main UAM applications

The main motivations for UAM deployment are illustrated in Figure 1: 1) the global trend of rising urbanization that has been seen since at least the middle of the 20th century; 2) the ever increasing pollutants emission due, for instance, to commuters using cars or buses; 3) the ongoing increase in traffic jams on the roadways of all the most populated cities; 4) the increase of carbon dioxide emissions, primarily attributable to transportation by vehicle. The idea of adopting electric-based transportation in metropolitan settings by utilizing the third dimension, i.e., vertical mobility, emerged in response to the existence of such significant drivers and the population's steadily growing sensitivity to themes of health and environment preservation.
As a result, an evaluation of the current and potential technologies that can support UAM has been carried out as part of the ASSURED UAM project. It is obvious that such novel transport methods must first be supported by the appropriate technology. Overall, due to the potential exploitation of technologies already taken into account in the area of unmanned aerial systems (UAS) and remotely piloted aircraft systems (RPAS), the enabling UAM technologies have matured to a good degree, but not enough to allow for their immediate deployment into service.
Short Take-Off and Landing (STOL), Vertical Take-Off and Landing (VTOL), Personal Air Transport System (PATS) vehicles as well as cargo drones are the primary aeronautical technologies for UAM-based transport applications. Their most likely and appropriate powertrain technologies are electric engines fed by batteries or by fuel cells. For both such energy sources, first of all batteries, the availability of high-density storage capable technologies, envisaged by 2030, represents a key enabler for massive implementation. In this way, such vehicles will be powered with low or zero emission propulsion systems that are able to assure proper range and endurance performances for real world

effective application. On the contrary, hybrid-electric propulsion employing traditional gasoline for the thermal energy provision appears to be severely constrained by the current and future pollution limits that will limit or prevent its use by 2035. As a tangible result, the most appropriate option is anticipated to be electric VTOLs (eVTOLs).

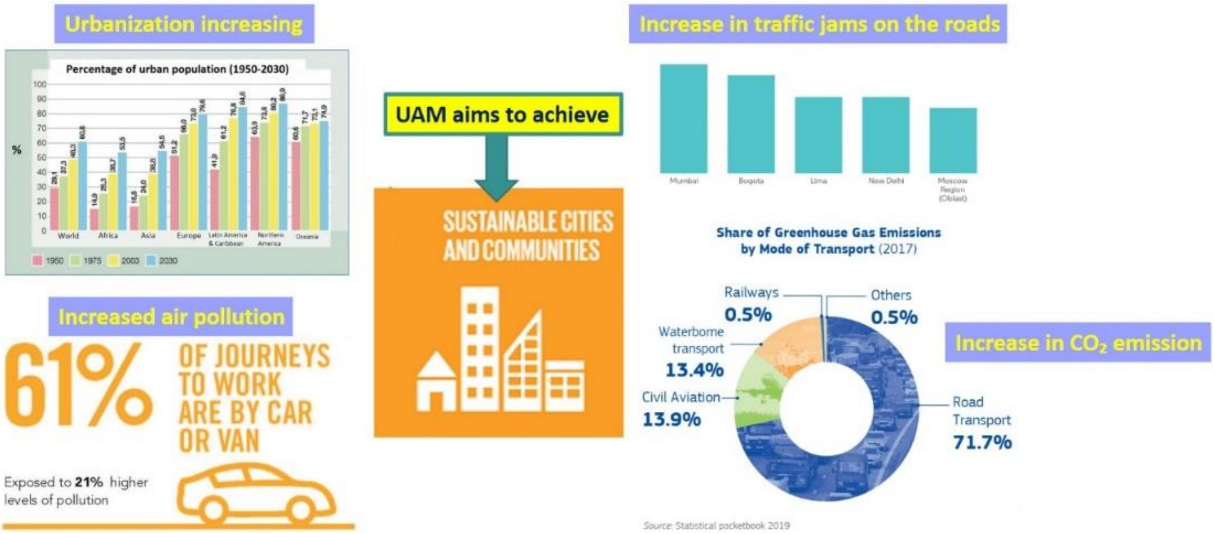

Figure 1. UAM implementation drivers

In terms of vehicles configuration, then, the main considered alternatives are multirotor systems, decoupled propulsion, tilt-rotor. In selecting them also noise consideration has to be taken, because noise associated with the selected configuration is anticipated to be a significant concern: to have real possibilities of application over the existing helicopters, eVTOLs noise emissions are requested to be 15 decibels (dB) below existing light helicopters (i.e. 70 dB at 500 feet vs 85 dB). For passengers transport, their needed payload would range from 100 kg (assuming one passenger onboard) to 960 kg (assuming none passengers and luggage onboard). It is finally obvious that acceptance of eVTOLs operations is subject to assurance of safety level not lower than the typical ones of general aviation aircraft. In their operations, then, eVTOLs are expected to be operated as fleets owned by companies, which will act as service providers and will have the possibility to lower the purchase cost per vehicle. Finally, the operations of UAM into lower airspace will require existence of dedicated U-space services, whereas the practical deployment of the services to passengers will need to be assured by physical infrastructures, the so-called vertiports. The communications will need to be assured by the presence of high bandwidth ICT infrastructures, which will follow an incremental deployment path that will advance gradually toward its final 2050 vision. The total findings of the ASSURED UAM technological readiness investigations are provided in [2],[5]-[6].

3. ASSURED UAM Use Cases

Based on the primary UAM cargo and passenger mobility services identified categories, the most relevant use case scenarios were defined, including the description of the expected operations, involved actors, regulations and procedures. The Advanced Air Mobility (AAM) concept emerged by incorporating use cases not specific to operations in urban environments, such as commercial use (intercity and intra-city), cargo delivery, public services, and private/leisure vehicles. Because of this, the AAM discusses the broadest range of opportunities in passenger and cargo transport in urban and peri-urban areas, including the description of VTOL and eVTOL efficiency, safety, and eco-friendly people and goods transport in the field of logistics in a new scale of the urban transport. In the project, a selection of the use cases that are indeed applicable to urban mobility scenarios and that can have relevance for the public utility and services has been carried out. This means that, among the initially examined main UAM applications, a subset considered more relevant under the indicated perspective has been selected and studied in details. The overall set of main UAM applications included:

- Cargo applications: transport of goods, transport of organs, emergency supply delivery;
- Passengers applications: transport of people, air ambulance, search and rescue in case of disaster;
- Other applications: infrastructure inspections, precision agriculture, environmental monitoring, land and builds monitoring.

After first examination, only the cargo and passengers' applications were retained for further studies in the project (Figure 2), being the other applications not relevant in terms of possible everyday applications and/or public benefit related applications. For instance, infrastructure inspection is neither executed on daily basis nor aimed to provide a transport service to general public, so it is not relevant for integration of UAM into cities.

Figure 2. Cargo and Passengers UAM applications

Among the cargo and passenger applications, then, the most relevant were further examined and the related use case were defined in details, as indicated in the following Figure 3.

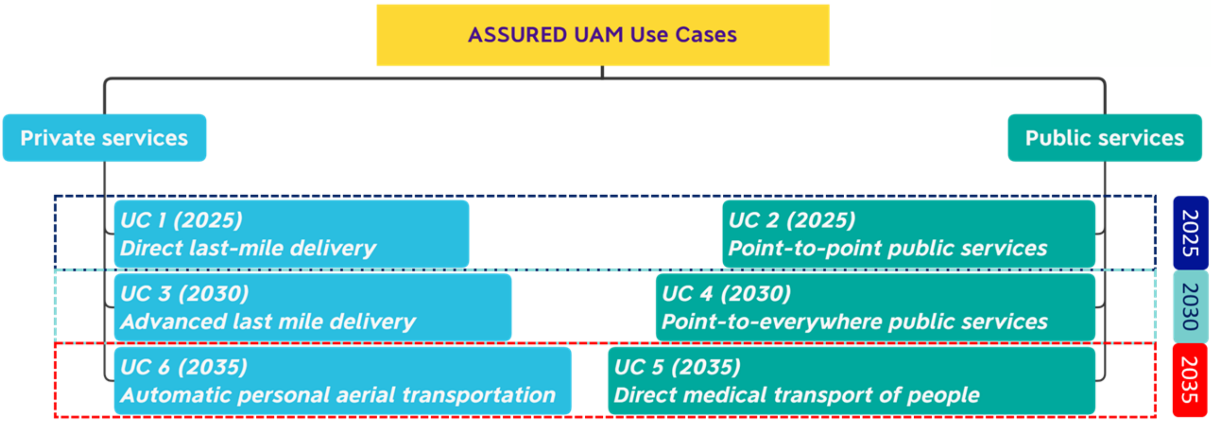

Figure 3. ASSURED UAM developed Use Cases up to 2035 time horizon

For each of the most probable Use Cases within the three time horizons addressed in the project (2025, 2030, 2035) indicated in Figure 3, detailed studies were carried out in order to describe them in terms of applicable aspects of interest, such as: type of operation, evolution of Technology Readiness Level (TRL), expected regulations, differences in terms of payload size and type, maximum flight distance, mission profile, required U-space services level, flight mode, regulatory framework, operations management, UAS configuration and components, ground infrastructure, ICT solutions and integration aspects within surface transport modes.
In the following of the paper, the ASSURED UAM project defined Use Cases for UAM applications into cities up to 2035 time horizon are outlined.

- ***UC2025|1 – Direct last-mile delivery (Private Services)***

It is one of the first drone transport operations that is typically thought to be used in urban areas. Due to the mission's relative simplicity, it enables the gathering of first experiences required for operations that are more complicated and focused toward actual market needs (advanced last mile deliveries). Initial automated operations are anticipated to be overseen by a human operator during test implementation. Simple local transportation of small, light packages from a predetermined distribution point to final locations that is driven by business needs, intended to replace underutilized cars and light trucks employed for courier deliveries.
The area that is covered includes the downtown/city center (where residential and commercial activities take place), densely populated residential neighborhoods close to the city center, and suburban shopping and commercial districts. The main area of activity is anticipated to be focused on less demanding environments with regard to aerial obstacles, flight conditions, and constraints.
UAM is characterized by private logistics services for small businesses (big malls in suburban skirts and small business areas in the city centre). Operations will include parcel lockers on the rooftops of public or private buildings or in a designated public space area, which make up the last mile of the city's intermodal logistic hub. The place where the flight ends is not surrounded by a lot of people.

- ***UC2025|2 – Point-to-point public services (Public Services)***

It carries out high-priority public service-related task within the context of a public-private partnership, enabling operations that are burdened by increased business risk but are nonetheless in the public interest (i.e., medical transport of blood, medicines, medical samples, or other light loads). Operations closely link public management sites like hospitals, labs, or other organizations providing public services.
With the support of a hospital intermodal logistic hub and a helipad at a local medical service facility situated in a low-density populated area, the UC provides healthcare for large hospitals, healthcare campuses, and local medical services (pharmacy, medical clinic).

- ***UC2030|3 – Advanced last mile delivery (Private Services)***

Last-mile deliveries, but more complicated than in the UC2025|1 and able to deliver multiple packages in a single trip, thanks to the employment of larger carriers. Fully automated processes will still require human supervision, but there will be a lot less need for human intervention, allowing for a higher volume of activities.
Downtown and city center (residential and business functions), densely populated residential neighborhoods close to the city center, suburban shopping and commerce areas connected to big malls in suburban skirts, and small business areas in the city center are served by private logistics services based on a last mile city center intermodal logistics hub, parcel lockers spread out in the rooftop of public or private buildings, or in a designated open public space.

- ***UC2030|4 – Point-to-everywhere public (Public Services)***

The high level of public interest in tasks related to high-priority public services (complex and risky tasks, like medical transport of first aid supplies, blood, medications, medical samples, or other light loads that can be given directly to or from the accident site) makes possible riskier operations that are intended to directly connect public management points like hospitals, laboratories, or other entities, to accident sites whose location is not pre-determined, as obvious.
The applications cover large hospital campuses, any locations in served zones of the city that provide healthcare, public safety, and emergency management, as well as any open space on the ground or in elevated structures (as long as it satisfies the minimal safety standards for takeoff and landing).

- ***UC 2035|5 – Direct medical transport of people (Public Services)***

In the beginning, direct test operations are supervised by a human operator within a single metropolitan area, enabling the unmanned medical transport, between hospitals, of qualified passengers/patients who will not need medical assistance during flight, providing in this way fast and direct healthcare services between large hospital campuses using, hospital heliports for flight take-off and landing.

This kind of application will make it possible to get the knowledge needed to replace, over time, conventional helicopter emergency medical services with more sophisticated, commercial unmanned passenger transport operations.

- ***UC2035|6 – Automatic personal aerial transport (Private Services)***

Aircraft concepts that are expected to be certified and available on the market by 2035 will enable air vehicles to access densely populated regions while coexisting with unmanned aircraft. Only optionally manned aircraft in automated flight mode (autopilot engaged) will be permitted to enter U-space managed airspace, paving the way for the subsequent future era of completely autonomous passenger operations. However, entirely pilotless missions will not be still feasible up to 2035 time horizon.
Based on a multimodal transport hub that includes heliports close to the railway station, ports, and airports, connected to the urban road, rail, and water transport to deliver events and tourism passengers to the destination heliport, the operations, initially assisted by human pilot in the aircraft, will be permitted to take-off and land in mixed traffic airports/vertiports, in an automatic manner.

The following Table 1 summarizes the deployment objectives for Use Cases for each considered time horizon up to 2035 scenario.

Table 1. Use Case deployment objectives

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

- ***The 2050 outlook***

Based on the identified use case up to 2035, it results that cargo applications are expected to be completely deployed by 2030, whereas initial test applications for passengers transport will be in place by 2035.
As indicated in section 1, then, ASSURED UAM worked in parallel and close cooperation with X-TEAM D2D project, where the covered time horizon was up to 2050. X-TEAM D2D studies predict that the people-transport applications will reach full maturity by 2050 and some relevant considerations that have been incorporated into ASSURED UAM in terms of outlook for UAM beyond the project scope are summarized in the following:

- It is reasonable to assume that unmanned passenger transport will be possible in a mature way in 2050 (beyond the 2035 time horizon considered in the scope of the ASSURED UAM project).
- By 2050, suitable architecture of overall intermodal transport system will have been implemented.
- Many possible modes of transport will be available in this timeframe, where clearly UAM plays a crucial role.
- A Total Traffic Management (TTM) system is envisaged, as an extended ATM operating concept for passenger services, addressing the integrated mobility service, as depicted in the following Figure 4.
- U-space complete services will be available at this time. Cooperative Intelligent Transport Systems (C-ITS) will use all aspects of cooperative, connected and automated vehicles. Mobility-as-a-Service (MaaS) will be possible for every traveller, including the flight segment.

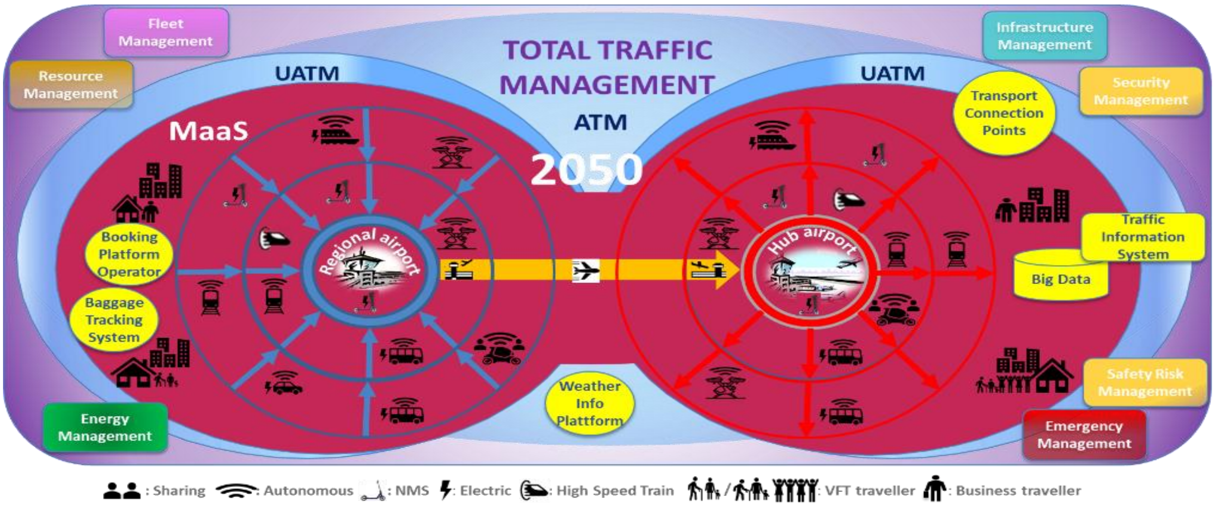

Figure 4. Total Traffic Management concept (2050 time horizon) from the X-TEAM D2D project [12]

4. Conclusions

The ASSURED UAM project designed the Concept of Operations for the integration of UAM into urban and peri-urban mobility system, according to multiple time horizons (5, 10, and 15 years). Based on the designed ConOps, six incremental main use cases (UAM operational models), two for each considered time horizon (2025, 2030 and 2035), have been defined, relying on the fundamental assumption that public services will be the booster for implementation of UAM on wide scale, thanks to the inherent support to public acceptance due to the acknowledge of public utility of the initial UAM related applications. Private services will start from logistics perspective and, then, once consolidated, and thanks to public services support to public acceptance, will move towards passengers transport, which will be only initially tested by 2035 and is expected to be fully matured by 2050 time horizon.

In this paper, an outline of the ASSURED UAM designed use cases has been provided, starting from the analysis of overall identified possible UAM applications and, then, specifically focusing on the description of the six main use cases considered as relevant for the application under the wider societal benefits point of view. These use cases have been briefly described and their specificities in terms of expected operational environment, needed technological enablers, envisaged regulatory implications, and main technical aspects have been outlined.

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