Acceptance, Safety and Sustainability Recommendations for Efficient Deployment of UAM - Outline of H2020 CSA Project

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Abstract. The vision of a third dimension added to hitherto nearly flat urban/metropolitan transport system gained the potential to become a mobility revolution for both logistics operators and, in the near future, for passengers as well. In spite of the expected emergence of this new form of transport and respective benefits for the efficiency of the mobility system at urban and suburban scale, UAM implementation also involves unprecedented and numerous challenges for cities and for all local public and private stakeholders. The local governing bodies are expected to provide policy, regulations and guidance for the implementation of UAM and to assure its integration with the ground mobility systems as well as with other urban functionalities. Taking into account both potential benefits and associated challenges related to UAM implementation, ASSURED-UAM (Acceptance, Safety and SUstainability Recommendations for Efficient Deployment of UAM) project, funded by the H2020 Programme, aims to support that effort, by providing a multidisciplinary study on operational and policy frameworks for the process of the introduction of unmanned modes of UAM.
1. Introduction

ASSURED-UAM project is CSA funded under Horizon 2020 programme. The Grant Agreement number is 101006696. It started on 1st of January 2021 and will conclude on 30th April 2023. It is coordinated by ILOT - Lukasiewicz Research Network – Institute of Aviation, Poland. Partners are: CIRA - Centro Italiano Ricerche Aerospaziali SCPA, Italy, CEIIA – Centro de Engenharia e Desenvolvimento (Associaçao), Portugal, ISSNOVA - Institute for Sustainable Society and Innovation, Italy, DTA - Distretto Tecnologico Aerospaziale S.C. A R.L., Italy, GZM - Gornoslasko-Zaglebiowska Metropolia, Poland and NLR - Nederlands Lucht- en Ruimtevaartcentrum, Netherlands.

2. Project background and goals

New technologies which emerge in the field of remotely piloted and autonomous aircraft industry generate visions of large-scale presence of air mobility in future transport systems also in areas considered as unavailable or hardly available for air transport (like densely populated urban districts). It seems fully reasonable as adding of a new dimension to transport systems prone to expect significant increase of system capacity, improved accessibility and affordability to metropolitan transport services. Moreover, putting effort into development of vertical transport is considered as remedy for numerous transport related challenges as well as enabler to achieve strategic goals included in e.g. in EC or ACARE [1] documents. Undoubtedly Urban Air Mobility (UAM) represents such potential. However, in order to exploit it in optimal way, it is necessary to put some effort in preparations. Which needs to cover a set of areas in diverse domains and aim at building of required structures and interfaces. As it is detailed below, integrated UAM has to integrate two separable and unconnected so far domains: Aviation (represented by UAS technologies, ATM, etc.) and the city. And it has to be achieved in a manner which would satisfy the needs of both sides. ASSURED-UAM project is aiming at development of set of solutions which will assure requirements resulted from integration with ATM and city without compromising UAM acceptability, safety nor sustainability.

Urban Air Mobility (UAM) according to common understanding refers to transportation by air within or between urban areas. However, the detailed meaning of the notion is not officially defined. In example, according to ATM Master Plan [2] or SESAR Programme [2], for the purpose of the project it was assumed, UAM as means of transport of people or goods enabling D2D or near to D2D travel within or to densely populated urban areas. It relates to both manned and unmanned aircraft of different configurations.

The specific objective of ASSURED-UAM is to achieve the following high-level goals: The first one is to describe the future in terms of probable UAM sector development. Vertical urban transport should rather be considered as clearly pragmatic, economic factors driven mode of transport, part of sustainable and integrated transport system. Therefore ASSURED-UAM project will develop robust and plausible scenarios for progress in the field of urban and peri-urban air mobility. The second objective is to provide broad and comprehensive organizational and policy definition support for authorities, policy makers and urban industry organization in complex process of implementation of UAM and its integration with horizontal dimensions of urban and peri-urban mobility systems. The third objective is to accommodate and propagate aviation best practices, standards, recommendations and organizational solutions into city/municipal administrative and legislative structures dedicated to deployment of Urban Air Mobility services in near future. With the application of the Total UAM System approach. Objective number five is to become the first but robust answer on the European Green Deal [3] goals contributing to climate neutral urban transport in 2050. The last but not least is to provide recommendations for integration of surface modes under the umbrella of U-Space Air Traffic Management System.

The ASSURED-UAM project will consist of four main blocks reflected in the structure of the project. They are:

- Knowledge base development;
- Foresight scenarios development;
- Standards and recommendations definition;
- Specific project development support.
All blocks will produce content to be included in the final product of ASSURED-UAM project – guidelines provided in 8 languages.

3. Knowledge Base development
The first Block is devoted to elaborate and provide content to the knowledge base and guidelines, to identify and describe main factors determining future scenarios for Urban Air Mobility system in three time horizons: in 2025 (after next five years), in 2030 (after next 10 years) and in 2035 (after next 15 years) and finally, to identify 10 most promising use cases in terms of technical credibility, legal and regulatory framework and social benefits. It will deliver comprehensive description of legal, technical and urban transport related ambient of UAM development and deployment processes. It will be divided into three main parts: technology readiness review, regulatory framework and Urban mobility integration.

3.1. Technology readiness review
Main objective of this task will be to answer to the following question:

What forms of Urban Air Mobility are going to be feasible (sufficiently matured) after next 5, 10 and 15 years?

Within this task two main steps can be distinguished. First step will be review of current UAM projects with indication on TRL aimed. The review will cover all leading national, European and global activities concerning technologies related to all UAM components (airframe, propulsion, avionics systems and ICT). Second step will be identification, naming and description of all strongest factors and trends describing current progress path for these particular technologies. Findings from technology analysis will be included in guidelines dedicated to the cities interested in UAM service deployment and will enable decision makers to better prepare for rapidly changing market of UAMs services.

3.2. Regulatory framework
Current regulatory framework seems to be far behind technologies. However intensified effort is made in order to avoid blocking of progress by lack of regulatory standards (both on global and European level). Urban Air Mobility, analogically to other forms of aviation is expected to be regulated in numerous areas. In summary, main goal of this task is to answer the question:

What regulations are expected to be implemented in the coming years, in relation to manned and unmanned freight and passenger transport over densely populated urban areas?

Similarly as in case of previous one this task will consist of two steps. First will be revision of key documents and stands presented by main global regulatory organisations (ICAO, EASA, FAA, etc.) as well as numerous advisory groups organisations or agencies (NASA, EUROCAE, SESAR JU, ISO International, etc.) concerning approaches, visions related to regulation of different forms of UAM. Special focus will be placed on risk assessment tools and safety models with significant potential to be used in Urban Air Mobility. The study will cover all UAM system components and domains both related to manned and unmanned cargo and passenger transport over densely populated urban areas. The second step will be identification, naming and description of all strongest factors and trends present in current regulatory approach. Findings from regulatory framework analysis will be included in guidelines dedicated to the cities interested in UAM service deployment and will enable decision makers to better prepare for rapidly changing market of UAM services.

3.3. Urban mobility integration
Urban Air Mobility forms have to represent potential for integration within metropolitan transport systems. In order to make it possible, cities should have efficient tools to directly or indirectly create as well as manage city air transport. Depending on the series of UAM use cases specifications, the different
strategies and approaches for UAM integration with the surface transport should be taken. Therefore, the main objective of this task is to answer the following question:

*What are going to be the most adequate strategies for UAM integration with other means of (urban / metropolitan) transport systems after next 5, 10 and 15 years, in relation to manned and unmanned freight and passenger transport over densely populated urban areas?*

This task will contain two main activities. The first one will be devoted to the revision of most common strategies and approaches dedicated to the integration of urban and metropolitan transport system. Special focus should be placed on financing models (e.g. for public transport), as well as on available tools and smart solution - travel information, payment methods – single ticket, ITS, etc. The second one will be identification, naming and description of all strongest factors and trend-setting issues present in current integration strategies or forms. Findings from UAM integration devoted consideration will be included in guidelines dedicated to the cities interested in UAM service deployment and will enable decision makers to better prepare for rapidly changing market of UAM services.

3.4. Definition of Concept of Operation

Last step in process of knowledge block preparation will be definition of up to 10 most probable to appear in the urban transport system forms of Urban Air Mobility, according to three time-horizons (5, 10 and 15 years). For that reason the independent ConOpses regarding particular use cases will be defined. Use case as an operational models of manned and unmanned goods and passenger means with generally defined mission profiles will be the result of three drivers: technology (what will be technically feasible), regulatory framework (what will be legally approved) and urban structure specification (what seems to be most beneficial from the transport efficiency point of view).

The formulation of the use cases will take into account also the parallel activities that will be in place in the X-TEAM D2D project [5], under SESAR JU ER4 programme, in order to benefit from proper information exchange and harmonization of the approach, so to maximize the research effort under the overall H2020 programme. Specified use cases will be subject of foresight scenarios developed in second block. Process of scenarios development together with expert evaluation as well as ASSURED-UAM cities experiences will deliver content for more matured and embedded in the real world specification of the most robust forms of Urban Air Mobility. The final results of the ConOps definition will constitute the UAM modes of transport that will be the backbone of the guidelines that will be provided by the ASSURED-UAM project.

4. Scenarios for UAM in future integrated urban mobility system

Foresight will be one of main output from ASSURED-UAM project. It aims at providing policy and decision makers with knowledge about probable options of future with regard to the process of Urban Air Mobility deployment. Foresight scenarios will be developed in three time horizons: next 5, next 10 and next 15 years (for 2025, 2030 and 2035). They will focus on three main areas: Identification and foresight of all capability constraints potentially limiting future UAM operability; UAM use case system Life Cycle Cost assessment; and Financing and acceptability scenarios for UAM deployment.

All these scenarios, developed for three different areas will be finally compiled in order to deliver complex foresight scenarios for defined UAM use cases deployment in three time perspectives. According to UNDP Foresight is [6]:

*Processes of anticipation that identify opportunities and threats which may arise in mid- to long-term versions of the future. As a way of thinking, foresight also encourages innovation, strategic evaluation and the proactive shaping of the future.*

4.1. Operational Constraints

It concerns development of scenarios dealing with future’s options concerning spatial restrictions and limitations reducing resultant UAM use case transport efficiency and accessibility. It will cover issues like airspace capability and accessibility, land use aspects – availability of urban space for necessary
ground infrastructure (including requirements to be imposed on it) as well as regulatory, natural environment and privacy aspects. Output from this task will be UAM use cases accessibility and efficiency level expressed in form of measurable and comparable indicators enabling also comparison with other, surface modes of transport. In the process of scenarios development dedicated group of experts (thoroughly selected from Extended Advisory Board) will be involved. Dedicated interview and workshops are planned to support this analysis.

4.2. Life Cycle Cost estimation
It concerns development of scenarios per use case dealing with assessment of LCC and environmental footprint for defined UAM use cases. Conclusions concerning SAT-Rdmp key deliverable – Common Vision [7] indicate on several challenges related to the cost of design, certification, manufacturing, operation as well as utilisation of Small Aircraft dedicated to personalised transport of passenger on short, regional routes. The cost was considered as one of main bottlenecks preventing more common use of small aircraft in transport, therefore motivating specific initiatives to reduce SAT operational costs by, for instance, designing advanced avionics enabling single pilot operations in such aircraft category [8]. The same consideration may be applied if the Personal Air Transport System (PATS) is considered, as addressed in the PPlane (The Personal Plane) project [9]. This conclusion can be still adequate for some UAM use cases. Generally, getting information on possible cost estimation for entire product life cycle (including environmental footprint) is crucial from the sustainability aspects point of view. Finally, knowledge about the cost will provide cities with data enabling them the preparation of economic rationale standing behind decisions about investing of public money into given UAM use case. In the process of scenarios development dedicated group of experts (thoroughly selected from Extended Advisory Board) will be involved.

4.3. Financing and public acceptance
Third areas addressed with regards to scenarios development. Development of scenarios per use case dealing with future’s options concerning UAM use case financing of related investments and resultant level of public acceptance. For the purpose of this study, it will be assumed that the question of public acceptance for UAM use cases as covered by definition of appropriate standards and requirements (with regard to noise, emissions) or operational constraints studied do not exhaust the issue. It is also assumed that remain questions concerning inhabitant attitude to UAM can be easily compensated by potential benefits coming from given use case (expressed as e.g. affordability to UAM services and resultant benefits for citizen). Affordability in turn depends on city’s policy with regard to UAM use case financing (source, model – e.g. subsidizing). In the process of scenarios development dedicated group of experts (thoroughly selected from Extended Advisory Board) will be involved.

4.4. Foresight development
Detailed scenarios developed will be the key driver for final foresight of UAM deployment scenarios addressing the “popularity” of UAM use cases (expressed e.g. in number of operations). Appropriate soundness/robustness/strength weights will be allocated to 3 operational constraints, LCC and financing and acceptability scenarios. As they all have similar or common sets of key drivers, a set of scenarios presenting degree of conditions favourability will be resulted, representing the same the UAM use case potential attractiveness level. Behind every scenario specified monetary effort for the city as well as environmental footprint will be found for given use case and for three time-horizons. That effort expressed in form or with use of indicators enabling comparison with other means of transport will provide opportunity for the decision makers to conduct total cost-benefits analysis on higher level and evaluate/assess total attractiveness of defined UAM use-case for the city. For every scenario a set of recommended actions will be defined.
5. Standards and recommendations

Process of standards and recommendations definition included will cover four main areas: Infrastructure, urban Air Mobility integration with metropolitan transport system, Environment objectives and Policy and urban planning. According to CEN [10]:

A standard is a technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something.

Developed and proposed standards and recommendations will be widely consulted with all interested parties. Evaluated and agreed will be included in guidelines and learning materials devoted to propagate and disseminate project results.

5.1. Infrastructure certification

Urban Air Mobility is not new concept: helicopter emergency medical services and passenger transport with helicopters within cities and between cities are examples of current air mobility movements. However, new technology developments like drones and electrically propelled aircraft are likely to open up the market for new UAM aircraft with characteristics which will be more societally acceptable and allow for profitable business cases. As a consequence, ground based infrastructure enabling the urban air operations will also change. Infrastructure for UAM is expected to include items like heli/verti-pads, ground stations, energy supply system, lighting, passengers and emergency response facilities, etc. It has to be located in urban environment, among or on the roof of buildings, in some cases close to other transport nodes. Solutions proposed for UAM infrastructure should be inspired by those implemented in other aviation transport modes but also be tailored accordingly to the risks that are specific to the urban environment, like confined areas, GPS blockage and reflection, turbulence and electromagnetic interferences and compatibility.

5.2. Urban Air Mobility integration

Urban Air Mobility has to be integrated with both manned regular air traffic and city surface transport. It can be challenging and in fact demands establishment of a dedicated system. For what concerns the integration of UAM with regular air traffic, the system called U-Space (or UTM) is dedicated to manage unmanned traffic with respect to manned aviation and it can be also extended to provide the UAM transport system, as properly integrated with conventional air traffic, with also the needed flexibility demanded by city or metropolitan transport system. Standards and recommendations provided by ASSSURED-UAM will therefore cover: traffic management - U-SPACE/UTM, data-exchange, travel information and payments, as well as solutions assuring efficient deployment of mobility as service. The task activities will take into account and benefit from the activities of the ongoing SESAR ER funded project X-TEAM D2D [5], led by CIRA.

5.3. Environmental objectives

Despite quite large number of RPAS operations carried out every day around the world there is no any environmental standards defined with regards to noise nor pollutions emissions. Additionally, due to the fact that some of UAM modes of transport are expected to fly at lower altitudes than e.g. General Aviation traffic today, the currently used noise requirements modelling might not be adequate anymore (e.g. ECAC doc.29). Process of standards definition and proposing will be proceeded by broad study on possible environmental impact of massive UAM operations. Such elaboration beside emission restrictions (both during flying over citizens as well as around landing pads) will cover questions related to energy consumption in aircraft components production and utilisations phases (e.g. with regard to fuel cells) and interaction with urban natural environment (impact on birds population). Identification of optimal solutions in terms of standards and recommendations for environment protection will be supported mainly by knowledge regarding risk assessment, regulatory framework and trends developed as well as by conclusions resulted from scenarios developed and, in particular those concerning operational constraints and LCC.
5.4. Policy and urban planning
This area covers standards and recommendations dedicated to the city’s administrative and organisational side of UAM deployment process. Within the scope of this task policy and urban planning standards and recommendations framework will be designed to support all authorities in their policy making processes. It will cover organisational standards and procedures related to deployment and management of UAM infrastructure and operations. Then, the role of regulatory and standard authorities in the field of urban transport, urban planning, aviation and ATM, energy infrastructure and financing (and procuring) will be explored and related policy standards and recommendations will be derived. Additionally, urban planning issues and sustainable transport deployment will be addressed.

6. City projects support
Fourth main ASSURED-UAM activity block is dedicated to support current UAM launch aiming projects. In parallel to the: knowledge base preparation, foresight scenarios development as well as standards and recommendations creation processes, three thoroughly selected metropolitan areas make their preparations for Urban Air Mobility operations deployment. These are:

- Górnoślasko-Zaglebiowska Metropolis located in Upper-Silesian voivodship. In Poland.
- Bari metropolitan area. Southern Italy, over Adriatic Sea.
- Porto metropolitan area. Second largest city in Portugal.

As it is indicated below the cities represent high diversity in numerous areas such as: city structure, transport system network, ICT technologies advancement, historical determinants, industrial and economic profiles/pattern, culture as well as future challenges and societal needs. Their involvement in ASSURED-UAM project creates outstanding opportunity to deliver solutions characterised by large range of applicability for various locations.

6.1. GZM metropolitan area
Górnoślasko-Zaglebiowska Metropolis is a metropolitan association established in 2017 in place of Katowice Urban Area. It is a continuous polycentric urban area consisting of 41 municipalities covering area of 2516 square kilometers and populated by 2.2 million inhabitants. Metropolis GZM is the host of the Central European Drone Demonstrator, which in collaboration with other national institutions, works on adapting and providing the urban airspace for users. The goal of Metropolis GZM is to promote the UAV services, on a large scale however, and with repeatability, so that they become the every-day-use ones and would be performed by e.g. by local governments. The ultimate objective is that these services should be carried out autonomously. By participating in the ASSURED-UAM project, GZM intends to develop the scenarios for repetitive and scalable services which would respond the specific needs of the cities. By associating 41 cities, which are already, to varying degrees aware and involved in UAV issues, will take the opportunity to implement pilot services in accordance with various scenarios and study their attractiveness, operational and economic efficiency, in cities of different sizes and characteristics.

6.2. Bari metropolitan area
It is middle-sized city located in southern Italy, over Adriatic Sea. It is the second most important economic centre of mainland Southern Italy after Naples (and the third after Palermo, if Insular Italy is included). The city itself has a population of 320,257 inhabitants, over 116 square kilometres, while the urban area has 750,000 inhabitants. The metropolitan area has 1.3 million inhabitants. Within this project, DTA will create an osmotic communication channel between technology partners, who are focused in framing the UAM technology, infrastructural, standard and regulation development needs, and end users (Municipality of Bari and the whole Drone Living Lab), who needs to define and deploy a plan to implement UAM services.

6.3. Porto metropolitan area
Porto is one of the Iberian Peninsula's major urban areas. Porto city has a population of 237,559 and a metropolitan area with 2.4 million people (2019) in an area of 2,395 km², making it the second-largest
urban area in Portugal. It is recognized as a gamma-level global city by the Globalization and World Cities (GaWC) Study Group, the only Portuguese city besides Lisbon to be recognised as a global city. The municipality of Porto, in line with its declared participation to the EIP-SCC UAM initiative, will further its interest to introduce urban air mobility in a way to improve the quality of life of its citizens and further the services and economic fabric offered in the city, a long time entrepreneurial and industrial centre in the north of Portugal. As such, the municipality will pursue feasibility studies for the introduction of urban air mobility services from drones to passenger aircraft taking advantage of the materials supplied by ASSURED-UAM and taking into account the municipality’s own infrastructure and urban planning initiatives.

7. Project results
The project activities will result with 17 publicly available technical deliverables covering all aspects addressed in the project. However, the Guidelines and learning materials on UAM services deployment will be main output document including all outputs from ASSURED-UAM project. As dedicated to cities decision makers and other involved stakeholders it will provide among other:

- Introductory brochure to UAM addressed to general public,
- Foresight scenarios with guides providing knowledge how to use it and
- Summary of Standards and recommended practices, addressed to top and middle management in any institutions interested or affected by UAM integration in urban mobility.

Document will be delivered as PDF files in 8 language versions: English, Polish, Italian, Portuguese, Dutch, French and Spanish and German. Additionally, a series of 8 short video lessons (15-20 minutes length) will be produced and uploaded on MOOC platform and on project’s website via Vimeo channel. Lessons will be created under the MOOC philosophy and delivered in English.

References
[1] ACARE Strategic Research & Innovation Agenda 2017 update, EC FlightPath 2050.
[2] European ATM Master – Digitalising Europe’s Aviation Infrastructure - Executive view, 2020 Edition, https://www.atmmasterplan.eu/
[3] SESAR - Single European Sky ATM Research Joint Undertaking - Smart and Sustainable Aviation for Europe, https://www.sesarju.eu/
[4] EC The European Green Deal, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[5] Di Vito V, Dziugiel B, Meincke P A, Mujica Mota M, Bagamanova M, Duca G et alii 2021 Advancements in the X-TEAM D2D Project: An outline of a Concept of Operations for integration of ATM and air transport into multimodal transport system for Door-to-Door travel. 11th SESAR Innovation Days 2021, SID 2021, 07-09 December 2021.
[6] United Nations Development Programme - Foresight Manual – Empowered Futures https://undp.org
[7] SAT-Roadmap FP7 CSA project, D1.1 COMMON VISION on the development of a Small Aircraft Transportation system
[8] Di Vito V, Mercogliano P, Beran J, Sapakova M, Maslowski P, Grzybowksi P and Rogalski T 2017 Selected Avionic Technologies in the COAST project for Small Air Transport Vehicles. 7th EASN 2017 International Conference on Innovation in European Aeronautics Research, Warsaw (Poland), 26-29 September, 2017.
[9] Di Vito V, Gabard J-F, Filippone E, Morani G, Le Tallec C, Giulietti F, Gatti M, Keshales B, Greenberg S, Delic M, Fassois S D, Michailides P G and Mastrapostolis T 2012 Automation and Control Architectures for the Personal Plane Project. AUVSI Israel International Conference, Tel Aviv, Israel, March 20-22, 2012.
[10] CEN – European Committee for Standardisation, www.cen.eu