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Implementing Urban Air Mobility in a Multi-Level Regulatory Framework: Perspectives from the EU

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Abstract – This paper discusses the challenges arising from the extended use of Unmanned Aircraft Systems (UAS) within urban contexts targeting people and freight mobility purposes. First of all, drivers and barriers are examined from the operational and planner's perspective, considering Urban Air Mobility (UAM) as part of the future transportation ecosystem. After a brief overview of the relevant European Union (EU) regulatory framework, issues concerning access to ground infrastructure and U-space governance will be examined, with a focus on Article 18(f) Regulation (EU) 2021/664 and recent European Union Aviation Safety Agency (EASA) guidance on this provision (AMC-GM). A uniform EU regime on UAM, as part of a strategy encompassing Innovative Air Mobility (IAM) as a whole, should be implemented with a certain degree of flexibility in order to adapt it to the peculiarities of each area, especially as far as access to airspace and ground infrastructure (vertiports, etc.) is concerned. For this reason, the role of local authorities remains crucial.

I. INTRODUCTION

Unmanned Aircraft Systems (UAS, i.e. drones)** have been largely used for monitoring and surveillance purposes [1, 2], while mobility applications, such as air taxis and last-mile deliveries, are still under investigation. According to EU regulators, the latter uses fall into the broad notion of Innovative Air Mobility (IAM), including operations with novel aircraft designs (such as vertical take-off and landing - VTOL, electric propulsion, etc.) aimed at offering a new air mobility of people and cargo and «based on an integrated air and ground-based infrastructure» [3, p. 6 ff.]. IAM applications to an urban context, referred to as Urban Air Mobility (UAM), represent a significant challenge for policy-makers and local stakeholders. As far as UAM is concerned, both autonomous vehicles issues [4] and air mobility regulation criticalities are involved [5].

The Drone Strategy 2.0 recently published by the European Commission (hereafter: the Commission) envisages UAM as a mean to enhance a more sustainable, less polluting, less congesting and safer urban transport system [6].

This paper discusses some of the challenges arising from UAM in terms of urban planning and regulatory options. First of all, drivers and barriers to a large-scale use of drones within the European urban context will be examined (paras. 2-3). Then, the analysis will address the EU regulatory framework, with a focus on issues concerning access to ground infrastructure and U-space governance (paras. 4-5). In conclusion, some remarks about the role of local authorities will be made (para. 6).

II. AIR MOBILITY AS PART OF URBAN TRANSPORTATION ECOSYSTEM

To highlight added value coming from UAMs solutions, core components of transportation system [7] may be considered. Main challenges may be seen indeed through the lens of modes, infrastructures, networks and flows (Fig.1).

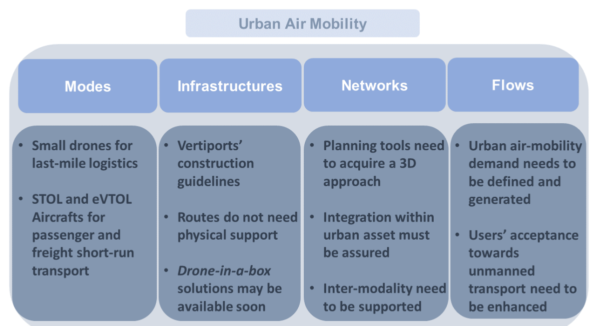

Figure 1 UAM core components

As far as modes are concerned, vehicles represent the pivotal element to be assessed. As underlined, UAS range is extremely wide and variated [8]; nevertheless, transport of goods and mobility services involve specific types of UAS, such as *a*) small drones for cargo delivery operations; *b*) short take-off and landing (STOL) aircraft to minimize surface congestion; *c*) electrically powered aircraft capable of vertical take-off and landing (eVTOL aircrafts).

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** According to Article 2(1) Reg. (EU) 2019/947, 'unmanned aircraft system' ('UAS') means «an unmanned aircraft and the equipment to control it remotely».

On one hand, the first category (sub *a*) may support traditional retail and *e-commerce* delivery services in last-mile logistics [9, 10], thus limiting externalities in terms of road congestion. On the other hand, STOL and eVTOL aircrafts are more suitable for passenger and larger freight transport.

In terms of transportation systems, infrastructures are one of the most critical elements. For this reason, regulators such as EASA are already implementing guidelines for vertiports' construction [11]. Compared to terrestrial means of transport, the need for physical infrastructures is more limited, except for terminals, which require specifical features and regulation (see, *infra,* para. 4). At the same time, -*drone-in-a-box* solutions have been recently implemented, thus minimizing requirements for spatial and terrestrial support and interventions for terminals too. Main challenges would be represented by vertiports' integration within urban environment, so that take-off and landing operations do not interfere with other urban activities and functionalities. In densely built cities, vertiport insertion may prove difficult but UAS may be also more strategically useful to ease congestion. This is one of the core research issues concerning vehicle technology too: vertical take-off functionality is currently under implementation in order to minimize land consumption.

From networks' point of view, mobility planning will play a pivotal role. In terms of strategical and sustainable development, main goal would be to support an integrated approach were UAM solutions are included within Sustainable Urban Mobility Plans (SUMPs) actions and not simply added *ex post.*

At the same time, the introduction of air-borne urban mobility requires a deep change in local authorities' and planners' mindset to develop innovative strategies and re-define urban schemes to support inter-modal integration (cf. Article 18(f) Reg. (EU), *infra*, para. 5): a third dimension must be added to 2D traditional planning. In this perspective, planning tools would be central not only in term of physical infrastructures integration, thus reducing interferences and enhancing synergies, but also looking at service integration through Mobility-as-a-Service solutions [12].

Maximum potential in terms of urban transport efficiency may be reached indeed only through a real intermodal approach towards city mobility and logistics challenges [13]. Full inter-modality requires strong efforts as well in terms of building a sufficiently dense network to make UAS services efficient and performative, ensuring last-mile perspective optimisation, thus preserving urban asset and safety. In this direction, modularity and seamless continuity could represent the keys to define an effective and sustainable transport system.

Finally, flows represent a 'great unknown' of UAM development: mobility demand for short-run air transport is to be defined [14]. In addition to usual issues in terms of assessing and quantifying potential users for new mobility services, main uncertainties are linked to autonomous vehicle acceptance [15]. As for terrestrial vehicles, fears and doubts about the reliability of unmanned transportation represent indeed the stronger barrier towards UAM services implementation. Reliability, safety, privacy, light and visual pollution, acoustic and polluting emissions production, animal disturbance are often cited indeed as critical elements in terms of societal acceptability and availability to use urban air-borne solutions among users [16, 17].

III. POTENTIAL DRIVERS AND BARRIERS OF UAM

Once urban air mobility is framed within transport geography traditional approach, an interesting look may come from the assessment of its main values and criticalities through the lens of a SWOT Analysis (Fig.2).

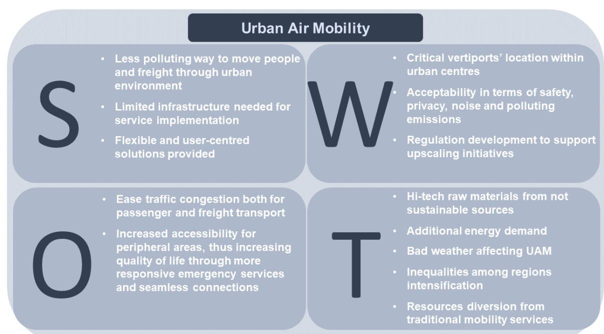

Figure 2 SWOT Analysis for Urban Air Mobility

In terms of strengths, UAS may prove to be a less polluting way to move people and freight through urban environment, being they usually based on fully-electric technologies, while private cars fleet and public transport as well are still heavily dependent on non-sustainable fuels [18]. It must be remembered that this emissions' reduction may affect urban areas, whereas referring to global emissions, attention must be paid to energy source for the required electricity, so that pollutant production may vary significantly from one context to another depending on the carbon intensity of energy local system.

Moreover, terminals and related infrastructure do not need a physical network, so links to peripheral and remote areas, both urban and rural, might be achieved by spending less than building road or rail infrastructure (even though charging services, maintenance, security and other operational costs have to be considered) [19]. Similar solutions may lead to the reduction of travel times and to the enhancement of metropolitan relations between cities and surrounding areas.

This prove to be extremely punctual, speaking of the flexibility and user-centred nature of this kind of transportation. The absence of travelling personnel and the possibility to manage this air-borne service in an automated way could lead to the definition of on-demand services meeting specifical users' needs [20].

It must be said also that some weaknesses emerge evidently. Despite a first attempt to tackle the issue in project guidelines on vertiports [11], terminal location may prove extremely critical. Vertiports are needed in central areas of the city to guarantee accessibility and last-mile optimisation [21]. Differently from traditional airports, usually located at the outskirts of town, these infrastructures require privileged urban sites that cannot be easily found within many of the biggest and consolidated cities, so that their efficiency may be undermined from the very beginning [22]. In this direction, a strong effort coming from policy-makers and local planners will be required to balance different interests insisting on central areas [23; cf. *infra*, para. 4].

As it has already been said, users' suspicion towards unmanned solutions is still strong and acceptability of UAM services represents one the main barriers, so that quantifying mobility demand for UAS-based transport services may prove to be extremely uncertain and vague [24]. Moreover, in order to fine-tune this kind of demand mobility services, details should be defined and deepened: in fact, not simple transport and efficiency elements, but qualitative and perceptive features affect users' modal choices [25].

In parallel to terrestrial applications, legal framework still needs strong support and advancement in terms of making unmanned solutions safe and fully regulated outside limited test-beds and within ordinary urban uncontrolled environment. Safety concerns may affect the up-scaling of similar initiatives in terms of interaction with the pre-existing urban ecosystem and regarding "traffic" regulation and air vehicles flow management [26].

Looking at surrounding context, the main opportunities are linked to the reduction of traffic congestion, especially in terms of freight transport where significant economy of scale are possible, without relevant infrastructural costs. This may lead to relevant benefits in territorial cohesion and social inclusion.

Relevant time savings could be reached, thus making peripheral areas more accessible and supporting new development paths for remote regions. Similar solutions in this direction may also contribute significantly to make emergency services more effective and responsive, especially referring to outer areas and regions [27].

Nevertheless, several threats should be highlighted as well. First of all, sustainability of UAM may be undermined both from an environmental and social point of view. Highly-technological solutions may require raw materials coming from outside EU, where working condition and environmental rules respect may not be granted [28].

Electricity additional demand for UAS may require wider and more powerful local energy grids, so that further infrastructural interventions may be needed, thus implying more land consumption and environmental impact, also due to local power supplied by non-renewable sources.

Moreover, initial high implementation costs may facilitate richer regions and countries, thus making former inequalities stronger. Incoming UAM alternatives may indeed favour developed areas able to forerun pilot actions and to develop advanced legal and economic framework to foster innovative experiences [27].

It is worth noting that bad weather conditions at the moment strongly affect this kind of vehicles [29] so that only some areas and some season will be suitable for UAM applications and this may worsen due to climate change impacts. For this reason, urban integrated transport system should be thought as modular to make it really resilient towards sudden adverse events. However, as shown by recent experiences, technology improvements are reducing UAM dependency on weather conditions, so that this issue may be less and less relevant in the future.

Indeed, the long-term perspective that UAM solutions require may divert resources and investments from other public and shared urban transport initiatives that need to be supported in the meantime. UAM alternative is at the moment mostly an individual one, as far as taxi and on-demand solutions have been currently implemented. Moreover, UAM may represent a deeply disruptive innovation within mobility sector, impacting severely on other fields (e.g. Information Communication Technology-ICT and raw materials supply), so that particular attention should be paid to safety, security and competition issues (*infra*, para 4). Similar solutions might also represent a cheaper and safer autonomous alternative to helicopter rides. Thinking of future massive adoption, this may lead in the far future to congestion issues and criticalities similar to the terrestrial ones, while sustainable mobility plan strategies advise to favour shared and collective solutions in order to reduce traffic and space (being it terrestrial or aerial) consumption [30].

Finally, additional challenges may derive from the implementation of sectorial air-borne solutions (e.g. within industrial and port areas) that will need to rely on multi-level governance in order to not interfering with other transport modes and services. This would prove to be a quite critical issue, since initial planning steps will require a strong coordination and cooperation between public authorities, private companies and stakeholders.

In light of the above trends and scenarios, it is possible to briefly assess the EU legal framework applicable to UAM.

IV. UAM THROUGH THE LENS OF EU LAW: A BRIEF OVERVIEW

A market for UAM, albeit promising, has to develop yet, so choosing the appropriate policy approach is a difficult exercise for legislators and regulators. On one hand, uniformity in rules improves safety and provides the legal certainty needed to foster attractiveness for investors. On the other hand, if the legal regime is too static and top-down oriented, innovation risks being stifled. This conundrum has been the subject of study for the regulation of other disruptive technologies, such as digital platforms [see, among many, 31; 32 and also 33, p. 981 ff.].

Focusing on the European Union, the drafting of a harmonised regime for drone operations has been among Commission's priorities since the first 'drone strategy' [34]. As known, the EASA Basic Regulation provides only essential safety requirements for drones (see Articles 55 ff. and Annex IX Reg. (EU) 2018/1139), while more detailed rules for manufacturing and operating drones have been adopted via Commission implementing and delegated acts (Articles 57-58 Reg. (EU) 2018/1139; see, respectively, Delegated Reg. (EU) 2019/945 and Implementing Reg. (EU) 2019/947) [see 35].

EU legislation on UAS is founded on Article 100(2) of the Treaty on the Functioning of the European Union (TFEU), which empowers the Union to regulate air transport [36]. However, it is debatable whether UAM - and UAS in general - may fall into the notion of 'air transport', as in operational terms they appear quite different [cf. 35, p. 70 and *infra*].

In terms of content, EU policy on UAS operations is safety-oriented, and reflects the underlying proportionality principle (see Article 5(4) of the Treaty on European Union - TEU): the rules should take into the account the risks of the specific activity concerned, as well as the «characteristics of the area of operations, such as the population density, surface characteristics, and the presence of buildings» (Recital no. 5, Reg. (EU) 2019/947). According to this approach, three different UAS categories are identified, from lower to higher risk: *i*) open, *ii*) specific and *iii*) certified operations.

Due to the complexity and the risks related to urban environment, UAM operations fall into the 'certified category', as expressly stated for transportation of people and dangerous goods (Article 6(1)b(ii) Reg. (EU) 2019/947 and Article 40(1)b-c Reg. (EU) 2019/945) [6, p. 10; 37, p. 181; cf. 38, p. 322 ff.]. Nevertheless, technical features of the certified category still need to be specified [6, p. 11].

From an urban planning perspective, two prominent topics can be highlighted: *a*) positioning and management of vertiports (and ground infrastructure in general); *b*) UAS traffic management (UTM) and its integration in urban transport systems [39, 40].

With reference to the first topic, the Commission envisaged the introduction of a regulatory framework under the scope of the EASA Basic Regulation [6, p. 11]. So far, EASA policy seems oriented to distinguish between airports and vertiports and, by doing so, creates overlaps and defining issues (e.g., the case of VTOL operations by manned aircrafts) [11, p. 18; see 15; 41, p. 521 ff.]. Once harmonized rules for vertiports would be laid down at the EU level, then Member States have to implement them: solutions already in use for airports may offer a benchmark [for an example in Italy, see 42, 43].

Moreover, building UAM infrastructure implies different policy options: public investments have to comply with EU State aid law (Article 107 TFEU) [44, 45], while private intervention might rise antitrust concerns, especially when the infrastructure is regarded as a natural monopoly [46, p. 23]. Logistics companies, for instance, seem willing to build their own charging stations and vertiports for last-mile urban deliveries. In this case, if the owner of ground infrastructure denies access to its competitors, an abuse of dominance could be triggered (Article 102 TFEU) [see 47; with reference to airport infrastructure, cf. 48, esp. 145 and 158 ff.; 49;

50]. This issue could be addressed by regulators by imposing access to infrastructure under Fair, Reasonable and Non-Discriminatory (FRAND) terms [51, esp. 355; in general terms, cf. 52]. At the same time, the reduced bargaining power of local authorities against large private companies has to be taken into account. Some parallels can be drawn with port and airport sectors [see, respectively, 53, 54; 55], but this could be even more tangible in the case of UAS infrastructure, considering the involvement of tech giants (like Google or Amazon) [cf. 56, p. 4; competition issues related to UAS data flows are outside the scope of this paper, cf. 57, p. 25; 51; 46 p. 23-25; 58, esp. 138 ff.].

The latter consideration highlights the link between unmanned aviation and information technologies, which is particularly strong in the field of UAS traffic management. In the EU legal framework, UTM has been addressed under the notion of 'U-space' (see Implementing Regulations (EU) nos. 664, 665 and 666/2021). Developing U-space means establishing an airspace covering a certain geographical area where drone operations are allowed to take place via digital and automated services (Articles 2(1) and 2(2) Reg. (EU) 664/2021; certain operations, e.g., some of those falling under the 'open' category, however, remain outside the scope of this discipline, cf. Article 2(3) Reg. (EU) 664/2021). These services are supplied by U-space service providers, holding a certificate issued by the national competent authority (Articles 14 ff.; generally, the national authority in charge of ensuring civil aviation safety: Article 3(34) Reg. (EU) 2018/1139). Member States may also designate a single common information service provider in order to supply these services on an exclusive basis (Article 5(6) Reg. (EU) 664/2021).

Implementing U-space in an urban context requires an active role by local authorities [39]. So far, current EU legislation requests national competent authorities to «establish a mechanism to coordinate with other authorities and entities, including at local level, the designation of U-space airspace, the establishment of airspace restrictions for UAS within that U-space airspace and the determination of the U-space services to be provided in the U-space airspace» (Article 18(f) Reg. (EU) 664/2021). This approach reflects one of the cornerstones of EU law, the subsidiarity principle, according to which decisions are taken at the closest possible level to the citizen (Article 5(3) TEU) [on the implications for regulating airport infrastructures, see 59]. No reference to Article 18(f) can be found in the 'Drone strategy 2.0': indeed, the Commission envisages a consultation mechanism including local stakeholders and authorities, but focusing mostly on societal acceptance and noise mitigation issues (see 'pilot project Sustainable IAM Hub', an online platform to be developed by EASA) [6, p. 13].

Nevertheless, useful guidance on Article 18(f) has been recently provided by EASA 'Acceptable Means of Compliance and Guidance Material to Regulation (EU) 2021/664 on a regulatory framework for the U-space' (hereafter: AMC and GM), as it will be discussed below [60, esp. p. 130 ff.].

V. IMPLEMENTING U-SPACE: MULTI-LEVEL GOVERNANCE

According to EASA, coordination mechanism should be led by a 'U-space coordinator', an entity nominated by competent Member State's authorities at three different levels of governance (i.e., national, regional and local, see, AMC1, GM4.1(f) and GM5(a) on Article 18(f)) [60]. The U-space coordinator should consult with local and regional authorities (including municipalities, metropoles, prefectures, regions, airports and ports: GM1(d) on Article 18(f)) [60], and may avail of a 'U-space observatory' in charge of a multi-level vertical coordination (even if it can be established at each of the three governance layers, cf. GM2(b).1; GM4.1(f) on Article 18(f)) [[60]. The activities of the coordination mechanism are divided into three phases: *i*) planning, *ii*) execution and *iii*) review (GM2 and GM4 on Article 18(f)) [60].

During the planning phase, a hearing process may address technical requirements in light of public policy issues (GM4(d) on Article 18(f)) [60]. At the end of public consultations, the coordinator should adopt recommendations for U-space design (GM4.1(e)(3) on Article 18(f)) [60]. After U-space becomes operational (execution phase), the coordinator ensures that accident data and other relevant information are properly collected via digital infrastructure (GM4.2(d)-(e) on Article 18(f)) [60]. These data will enable improvements and adjustments during the review phase (GM4.3 on Article 18(f)) [60].

Some of the tasks of the coordination mechanism appear quite sensitive, such as *i*) reconciling regulation of the lowest parts of the airspace (at the EU level) and that of ground sites of interest and infrastructure (mainly at national and local level) and *ii*) integrating local traffic infrastructure with UAM (GM3(b)-(c) on Article 18(f)) [60].

To be effective, the above-mentioned mechanism will need implementing acts by Member States; however, some strengths and weaknesses appear *prima facie*. The bottom-up approach and stakeholder engagement seem suitable for gaining societal acceptance and sustainability in the long run, even if this could delay market upscaling. In relation to airspace use, coordination among public and private stakeholders is required, in order to effectively prioritize emergency UAS services in case of contingencies (Article 10.8, Reg. (EU) 664/2021, referring to Article 4, Impl. Reg. (EU) 923/2012; on public interest services, cf. Article 2(3)(a) Reg. (EU) 1139/2018).

The three-layer governance structure envisaged by EASA seems agreeable. However, if interpreted too narrowly by national authorities, it could lead to redundancies and multiplication of entities involved (e.g., the creation of U-space observatories at each layer), while the focus should remain on vertical coordination between regulators. Nevertheless, the model seems flexible enough to adapt technical regulations to local needs, especially as far as geography and integration with general urban planning is concerned. Sustainability has been addressed mostly in terms of noise pollution, while the environmental impact of low airspace navigation and ground infrastructure seems not enough explored. At the same time, modal integration with other systems of urban mobility requires coordination between EU and local authorities: some pilot projects are moving in this direction [61].

Future implementation of U-space could benefit also from experiences gained from airport (and port) governance. Though, differences cannot be overlooked, both in terms of modal integration and reliance on digital infrastructure and automation. In this vein, EU regulators seem better equipped to address issues like data management and cybersecurity [62].

VI. CONCLUSIONS

Urban Air Mobility may represent a unique, disruptive opportunity to make transport system more redundant, resilient, flexible and effective both for passengers and freights. Nevertheless integration, inclusiveness and sustainability should be pivotal element to shape a deeply innovative and comprehensive mobility eco-system for future cities.

EU is at the forefront in developing a comprehensive UAM regime. However, due to the complexity of the urban context, UAM and U-space implementation cannot rely on only a top-down approach, but requires coordination among different levels of regulation. While the European Commission still has to develop some of the relevant technical regulations, EASA guidance outlines a first governance model for UAM. If coupled with a pragmatic approach from Member States in order to avoid redundances and foster vertical coordination, this model could support the industry while ensuring sustainability and societal acceptance at the same time. In order to achieve these objectives, the role of local authorities will be crucial: this revolution in EU cities' design can only come through airspace and ground planning integration.

A holistic approach to transport planning and regulation, multi-level coordination and governance, as well as subsidiarity principle to guide land transformations may represent the key-elements to shape an innovative and disruptive model of urban mobility.

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