AiRMOUR

Guidebook for

Urban Air Mobility Integration

AiRMOUR Deliverable 6.4

Jonas Stjernberg
Philip Durnford
Patrick van Egmond
Jannik Krivohlavek
Renske Martijnse-Hartikka
Stian Andre Solbø
Felix Wachter
Katarina Wigler

Jonas Stjernberg, Philip Durnford, Patrick van Egmond,
Jannik Krivohlavek, Renske Martijnse-Hartikka,
Stian Andre Solbø, Felix Wachter & Katarina Wigler

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Table of Contents

Table of Figures

Glossary of terms

The AiRMOUR deliverable Foresight analysis offers an extended list of acronyms and terms. This addresses the terms used in this guidebook.

Abbreviation	Full term	Definition
	Air Taxi	Aircraft carrying passengers along typically short routes, which are not serviced by conventional civil aviation operators. Commonly used to describe commercial services.
ATC	Air Traffic Control	A service provided byground-based air traffic controllers who direct aircraft on the ground and through controlled airspace and can provide traffic information services to aircraft in uncontrolled airspace.
BVLOS	Beyond Visual Line of Sight	Sometimes also called BLOS, it describes BVLOS operations, where the flying of a drone is without a pilot always maintaining visual line of sight to the aircraft.
ConOps	Concept of Operations	A definition of operations, operational environments and applicable legislative and/or regulative framework documents
	Drone	Aircraft (Unmanned Aircraft – UA) or vehicle (e.g., underwater drones) designed to operate autonomously (without a human in control), automated (pre-programmed with the option for a human to take control at any time), remotely controlled (a remote pilot actively controls the drone). Also called Unmanned Aircraft Vehicle (UAV) or Unmanned Aircraft (UA) when referring to drone aircraft.
EASA	European Union Aviation Safety Agency	Agency of the European Union responsible for designing the civil aviation safety framework. EASA's mission is to promote the highest common standards of safety and environmental protection in civil aviation. The Agency develops common safety and environmental rules at the European level.
EMS	Emergency Medical Services	These are emergency or Urgent services providing sufficient pre-hospital treatment with on-site qualified medical care.
eVTOL	Electric Vertical Take-off and Landing aircraft	Helicopters or novel aircraft, that uses electrical propulsion to take-off, hover, and land vertically.
	Geofencing	A virtual geographic boundary defining a volume of airspace, which the autopilot of an aircraft will not cross in normal operating conditions.
	Strategic deconfliction	A service that before take-off ensures that different aircraft will not collide. Each new operation/flight plan is before take-off compared to other known operation/flight plans and a de-confliction in time or route is proposed.

Abbreviation	Full term	Definition
UAM	Urban Air Mobility	Extension of transportation systems at urban areas, or between those for distances that are not covered by regular aviation, in the third dimension – air.
UAM operator	Urban Air Mobility operator	Commercial stakeholder responsible for the practical operation of drones and Air Taxis, shall hold valid licenses and certifications from EASA.
	Route planning	Static or dynamic four-dimensional route planning for aircraft in a complex urban environment, considering multiple factors from the domains of air and ground risk, including the built environment, citizens, other existing transport mobility modes as well as environmental factors.
UAS	Unmanned Aircraft System	UA plus the necessary operation infrastructure and control units on ground and in air, such as data transmission infrastructure and other operation support systems or elements.
	U-space	A set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient, and secure access to airspace for large numbers of air vehicles. Not synonymous to 'U-space airspace'.
	Vertiport	Landing site designed specifically to support Vertical Take-Off and Landing operations, including taxiing, parking, and servicing of the aircraft as well a cargo and passenger handling facility.

Introduction

This guidebook is designed to help city and regional decision makers, as well as Urban Air Mobility (UAM) operators, understand whether and how investing in urban air mobility is likely to provide benefits. Additionally, the intention is to present what questions and elements are involved in implementing a successful and sustainable UAM service network. The guidebook is also relevant for other stakeholders in Europe, as it combines the four main points of view relevant to UAM: urban design and mobility; aviation safety; public acceptance and UAM integration process management.

The UAM Integration Guidebook is based on the work presented in the AiRMOUR deliverables, which were developed during the course of a three-year, Horizon 2020 research and innovation project.

The *Foresight analysis D2.1* highlighted how past trends are not sufficient as a basis for planning the future. On the one hand, the human needs of mobility and privacy are immutable. On the other hand, both innovation and the climate crisis challenge the status quo. We also consider physical factors, such as the urban space that is available for UAM and the growing battle for energy and raw materials. We aim to offer the reader insights on the decision making and value added of UAM in general, seen through the lens of Emergency Medical Services (EMS) with an expanded focus to other UAM applications where beneficial.

Figure 1: AiRMOUR early depiction of key stakeholders in UAM.

Many cities have recently engaged in the promotion of active and green modes of transport such as public transport, cycling and walking. Some of them have defined sustainability goals, sometimes including Sustainable Urban Mobility Plans (SUMP). For example, in AiRMOUR's partner city, Helsinki, the objective is to reduce greenhouse gas emissions by 69 per cent by 2035, from the level of 2005[1]. Reducing the environmental footprint of cities, while covering the citizens' needs for mobility, requires a) reducing the distances travelled[2], b) shifting the mobility mix towards lower emissions, c) increasing the number of people/goods per vehicle and d) reducing the quantities of materials and emissions per vehicle. However, some cases have very specific requirements that may be answered, thanks to UAM. Aviation has thrived in areas where geography poses a challenge. In hard-to-reach environments, for example in archipelago cities or in some peri-urban environments, airlifting will allow cities to provide a service rapidly without increasing and possibly even lowering societal and environmental cost compared to current alternatives. Similarly, in highly congested city centres, UAM can provide significant benefits for both society and business.

The UAM Integration Guidebook is a curated introduction to most AiRMOUR deliverables with links provided for further reading. The Guidebook has been refined in discussions with pilot and replicator cities and regions and other relevant stakeholders related to the integration of UAM and EMS.

Stockholm and Dubai have been active counterparts and sparring partners for all project partners, generating relevant inputs to all relevant points of the Guidebook. Their involvement has been crucial for the validation and verification of this work. Thank you.

Tour of the Guidebook

This guide is designed to be dipped-into by the reader. We invite you to go directly to the topics of interest, without having to read the book from beginning-to-end.

Visual boxes highlight take-aways and links to further reading.

In a nutshell:

Each chapter starts with a high-level summary of the content being developed in the following subparts. The box is designed to help the reader follow the main topics and navigate in the document.

Hyperlink box

The guidebook builds on several deliverables of the AiRMOUR project. Those boxes mention the document of reference that can be consulted to gain more knowledge on the topic discussed in the preceding lines and takes the reader to the download site.

The Horizon2020 “AiRMOUR” project

AiRMOUR presents an approach that takes on one of the most critical and challenging early real-life applications of UAM in Emergency Medical Services (EMS). AiRMOUR fills in the gaps and advances the understanding of needed near-future actions by urban communities, operators, regulators, academia, and businesses. AiRMOUR is a research and innovation project supporting the development of urban air mobility, via emergency medical services, supported by the European Union’s Horizon 2020 program.

The AiRMOUR project engages 13 following partner organizations:

1. VTT Technical Research Centre of Finland (Coordinator)
2. City of Stavanger
3. EHang Scandinavia AS
4. Forum Virium Helsinki Oy
5. Hochschule Kempten
6. Linköping University
7. Luftfartsverket / Swedish Civil Aviation Administration
8. LuxMobility S.A.R.L.
9. NORCE Norwegian Research Centre AS
10. Regionalmanagement Nordhessen GmbH
11. Robots Expert Finland Oy
12. Trafikverket / Swedish Transport Administration
13. University Medical Center Groningen

All deliverables from the program are shared on the website under the following link.

The content available on the AiRMOUR website shows the status report on progress of work packages related to the identification of the gaps and challenges and exploring the possible solutions or improvements that can be either implemented or further researched. The website will be updated with project proceedings until the end of the project in December 2023.

Insights from partner cities

In the preparation of this document, representatives from Helsinki, Northern Hesse, Luxembourg and Stavanger were consulted. Cities face the challenge of balancing needs on the following scales:

- **Top-down vs. bottom up:** Cities need to balance between implementing policies from the top with direct citizen feedback. The topic of citizen engagement was largely investigated within AiRMOUR and acknowledged as a critical success factor at the Amsterdam Drone Week 2023.
- **Collective vs. individual:** Important questions of balance are how large the target group is and to which extent does a solution need to satisfy every single citizen. This topic becomes particularly relevant, for example, when addressing people's needs for privacy and the need to intervene in people's lives.
- **Short term vs. long term:** City decision makers will need to compromise and clarify for themselves how long it should take before the benefits are felt by the population? How do elected officials sometimes elected for a few years balance the need related to a long-term strategy?
- **Incremental vs. disruptive:** Although a new paradigm may sometimes appear better, the existence of the status quo will require cities and UAM operators to explore how disruptive they can be. This topic becomes relevant when air risk and interactions between manned and unmanned is concerned but also ground infrastructure needs integration with the current.
- **Goals vs. means:** Are the cities adding technology or looking for use cases because a technology exists or is the project part of a larger scale plan? Siemens describes their smart city solution as a place where "countless automated systems will have a perfect knowledge of users' habits and energy use. The goal of this city…". The smart city imagined by Siemens would have a single goal. Does a city have one single goal? Who is deciding it? With what purpose in mind? Cities will find their answer to those questions.
- **Resource intensive vs efficient:** In a world where raw materials and energy get scarcer, how should cities weigh efficiency gains against resource requirements? For example, can a city in Germany think about the potential efficiency gains of UAM in the same way as a city in Norway, when electric energy in Germany causes 13 times more CO_2 emissions than in Norway?

City officials reported difficulties deciding between these trade-offs. Even when financial resources are available the human skills and resources may fall short to understand the complex topic at the crossroads between aviation, urban planning, and medical services.

In Luxembourg, it was reported that although public transportation is free of charge and efficient the residents preferred to use their cars resulting in daily congestion at peak hours. In many cities, the multiplication of political layers, i.e., local, supralocal, regional and national, combined with different interpretations of facts, led the decision-making process to a standstill rather than multiplying the effort. In the context of UAM, this guidebook explores how to break a standstill at those different levels and what influence the cities could have over the decisions.

In all cases, the requirements imposed on Urban Air Mobility by the regulators slow down the adoption and cities may choose their role to be precursor or follower. The adoption of a novel technology for mobility requires trials and integration in urban environments so that the population can make an informed decision about it. Integration and experiments are discussed in a later part of this document. When some cities may face challenges to reach out to populations speaking several languages, as in the case in Luxembourg, the opportunity to trial could be overcoming this challenge.

Insights from other cities

The main value-add of UAM is in the shortening of delivery times. According to expert interviews, there are differences between different European cities, not only in different local regulations, but also in the potential time savings from UAM leading to significant differences in the potential for UAM to add value. In cities, such as Hamburg with a large harbour and congested transportation routes though the city to the harbour, the potential for time savings from UAM is obvious. In Nordic countries, there are many slow-to reach areas, such as islands, and rural healthcare, which could benefit from drone deliveries.

1: Urban Air Mobility in a context

In a nutshell:

Urban Air Mobility should be considered in the context of mobility to satisfy the needs of society. The coming years will be disrupted by extreme events and see an increasing battle for materials and energy. This will likely limit the adoption rate of UAM and limit economic growth in all aspects of society.

UAM is not expected to reduce congestion and will only reduce the environmental footprint of transportation if applied correctly. The integration of UAM for EMS purposes should increase chain efficiencies, improve health outcomes from more rapid deliveries to accident scenes, provide faster path lab turnaround times well as improve the equity of care (for example rural vs. urban).

From transportation to mobility

A growing number of cities engage actively in improving mobility rather than transportation[1] and focus on impact rather than technology. Those concepts are further merged into the concept of "access" to goods and services, with the objective to provide citizens with what they might want or wish for, tangible or intangible, material or immaterial. Therefore, the foresight analysis looks beyond aviation technology to how air mobility may make a positive impact on the delivery of emergency medical services seen as one service most likely to benefit from the deployment of UAM.

However, a too narrow focus on highly sophisticated mobility systems introduces new risks. Ferreira et al. (2016)[3] state that "transport researchers are too focused on mobility and on making transport systems resistant to threats and disruptions". This approach "might eventually lead transport systems beyond an excessive complexity threshold, the point in which the intricacy of these systems becomes a threat to their own resilience and collapse occurs" as well as "weakens the […] localism […] and reduces people's opportunities to live and work close-by.".

Based on a thorough review of academic and business papers, online conferences, presentations and expert panels, workshops in partner cities, and expert one-to-one interview, the foresight analysis investigated trends, gaps, contradictions, expectations, and revealed valuable insights.

1 Mobility is the ability to freely move or be moved. The important difference here is the word ability. Transportation describes the act of moving something or someone (objective), whereas mobility ("capable of movement") describes the ability of a person to move or be moved (subjective). In this context 'transportation' should be seen as the capacity to move goods or people – the "technology", whereas 'mobility' is how goods and people are able to move around – the "impact of the technology".

Our first finding is that most UAM studies take systemic economic growth for granted and ignore macro trends, such as climate change, energy transition and scarcity of raw materials. The International Energy Agency or Intergovernmental Panel on Climate Change (IPCC) forecast that the future will be unlike anything we have known in the past. In Europe, the south parts are expected to experience unprecedented droughts while the north parts may experience heatwaves. Sea levels rise and floods will affect the entire continent. Not only will extreme events become more frequent and more severe, but climate change will also impact migrations in a world where finite resources are not half abundant as would be needed according to the predictions. The Lancet estimates that “climate change is the greatest global threat facing the world in the 21st century”. Optimizing emergency medical services in the context of resource scarcity and a changing climate is crucial.

The call for Urban Air Mobility

Air vehicles offer opportunities to link two places quickly and efficiently: places such as centres of 15-minute cities, hospitals and either remote islands or rural areas. Over recent years, millions of missions have been flown to deliver medicine with drones with viable economic models in Africa. In Sweden and in Denmark, Everdrone has completed over one thousand defibrillator delivery flights by drone directly integrated with the EMS system.

The AiRMOUR foresight analysis shows how economic feasibility of those emergency medical services is determined by two factors; the type of missions that are being flown and the value of life.

The implementation of such solutions requires the finding of synergies between aviation, emergency medical and city partners. Such agreement can only be found building a transverse understanding of the problems at hand by all actors. City decision makers will benefit from training to understand the strengths and opportunities coming with UAM, specifically related to understanding the potential services, the regulatory and safety framework within the UAM ecosystem and how it relates to the urban regulatory domain and the planning monopoly of the City as well as how to construct informed and meaningful public tenders for UAM-enabled services. Acceptance of the additional service is expected to be significantly higher when the public good is engaged, as is the case for emergency medical services.

It is noticeable that, due to the high complexity of both technology and regulations, supply of UAM enabled services is still very limited, and therefore real-world evidence of the usefulness of the services is largely missing, although significant research has been made in the narrow field of the usefulness of defibrillator deliveries with a drone.

The document “Foresight analysis and UAM EMS integration process management” is available for download here.

Functional requirements towards UAM for EMS

Recent technological advancement in automation, electrification, distributed propulsion, and sensors enable the design and operation of novel aircraft, which are expected to bring significant changes compared to conventional aircraft.

The integration of aircraft into the healthcare sector is not a new phenomenon. During the 20th century, airplanes as well as helicopters have been integrated into many EMS systems around the world. Airplanes are typically used where long distances need to be overcome in a fast manner as is needed for organ transport or repatriation, for example. The main missions of helicopters are to bring essential healthcare resources (supplies/equipment, personnel, combination) to a location rapidly and to transport patients to the right hospital if necessary. Both transportations means are costly to operate and create a high level of nuisance for the surrounding environment and public, which hampers the level of adoption within the EMS systems.

In most cases, the cost appears justified because the helicopter is either much faster than alternative modes of transportation (in a mountain emergency, for example) or that the societal cost of a lost life is higher than the financial cost of the operations.

This new generation of UAM aircraft aims to be more silent and more automated than conventional aircraft. Moreover, as most of them use electrical propulsion, the local emissions could be significantly reduced compared to traditional aviation. In the same manner as helicopters, UAM transportation is not affected by delaying road conditions such as traffic jams, bad road quality or road closures. Also, UAM aircraft are likely to offer weight gains compared to helicopters that decrease the overall emissions.

The maturity of UAM EMS ecosystems is currently still low. In Europe, regulations and a generally high-quality ground transportation network are two of the main reasons that slow down the implementation of UAM EMS.

However, novel electric aircraft are expected to benefit the healthcare systems in Europe by:

- Increasing access of hard-to-reach communities to healthcare resources,
- Enabling on-demand deliveries and decreasing (hospital) inventory,
- Reducing the response time for time critical out-of-hospital incidents, and
- Facilitating a larger adoption of home-based care in addition to hospital-based care.

There are two fundamental characteristics of a medical UAM mission:

- Type of landing zone: The landing zone can be either pre-determined, for example between medical facilities, or ad-hoc, such as a road accident at an arbitrary location.
- Type of payload (cargo vs. human[s]): The type of payload carried will influence the aircraft with the transportation of humans onboard requiring both some redundancy of systems as well as structural integrity to protect humans in hard landings. The cargo payload can be simple equipment (e.g., AEDs) or medication, biological products such as blood or tissue samples but also small medical devices. Humans to be carried can be medical specialists or patients.

For every use case, functional requirements clarify the needs of medical stakeholders. In every case, the needs to fulfil those must be weighed against the needs of the other stakeholders[4]. The functional requirements are one way to express the needs of the medical stakeholders in relation to UAM EMS missions. It was found that four categories are sufficient to define functional requirements in a structured way. These categories are:

- infrastructure (physical, digital, energy, airspace)
- vehicle capabilities
- regulatory/knowledge requirements, and
- operational requirements.

AiRMOUR identified four generic UAM-EMS use cases:

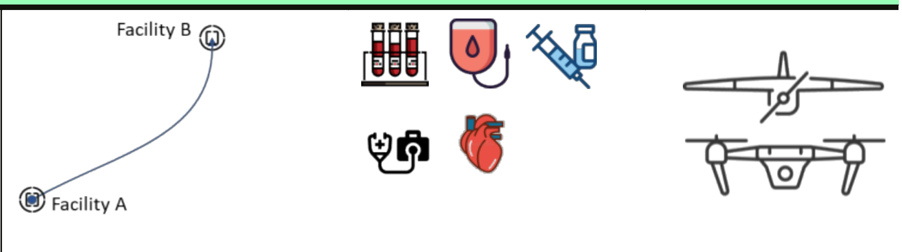
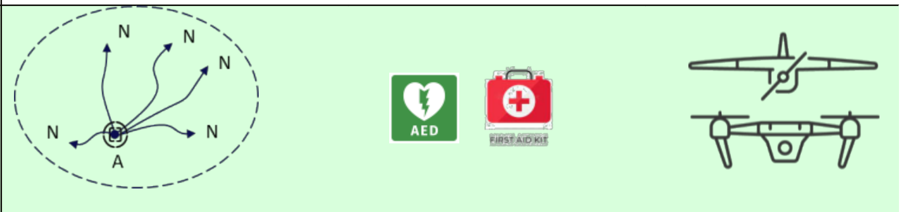
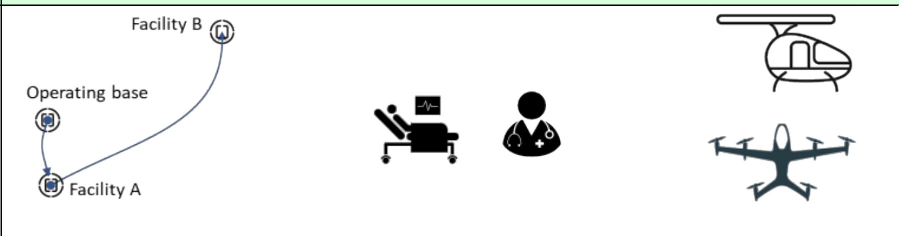
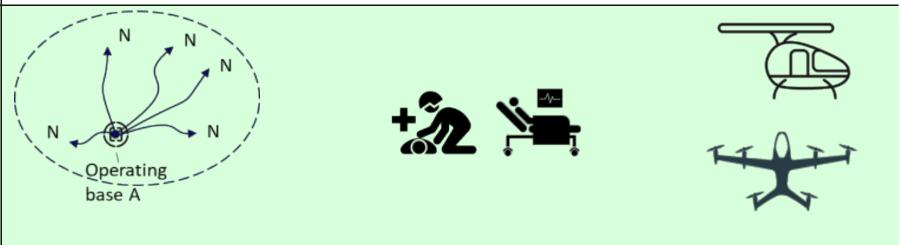
	Use case	Type of route / Possible payloads / Aircraft
I	**Drone** for **interfacility** transport of medical products	
II	**Drone** to bring medical products to an **ad-hoc** location	
III	Passenger-**eVTOLs** for **interfacility** transfer of medical passengers	
IV	Passenger-**eVTOLs** to transport medical staff to an **ad-hoc** location	

Figure 2: Breakdown of AiRMOUR UAM-EMS use cases.

As the UAM EMS ecosystem matures, it is expected that those functional requirements will evolve. For example, the operational availability (from good visibility at daytime to all weather operations) or the level of automation (from one pilot per aircraft to one pilot monitoring several simultaneous flights) will evolve. An improved maturity is expected to manifest as the following thresholds are met.

1. A pilot “testable” system

The aim is to prove safety in a real-world environment and to gain trust from relevant stakeholders. No direct customer value can be created; however, this step is necessary to mature the system to reach a minimum viable system. Several cities have already reached this step or are actively working towards achieving it. Some cities expressed frustration that too many initiatives stall at this early level due to lack of decision-maker support.

2. A minimum viable service

A minimum viable system is a service that meets a particular validated need of a target group (the end customer, possibly the policy makers), while it demonstrates the potential for commercial success for the UAM operator and demonstrates positive outcomes for all stakeholders.

3. A viable service

The viable service consists of all necessary systems integrated into the EMS workflow reaching its full potential. Vehicles, ground infrastructure, communications and charging systems are integrated and the logistical processes adapted at both ends of the flight for a seamless delivery. Imagining this “loveable” system in a holistic manner also requires description and meeting the societal, environmental, economic, and operational goals.

Among the main forces influencing the development of UAM, one may find:

- Regulatory framework (aviation, urban, medical) relevant to UAM EMS operations
- Industry standardization
- Public acceptance (e.g., noise, visual pollution, privacy-related aspects)
- Costs/business model

Based on stakeholder workshops in the AiRMOUR partner cities and regions, transportation missions targeting hard-to-reach areas such as islands seem to be among the most valuable use cases in the short term. This is due to slow or expensive alternative transportation means such as ferries or helicopters.

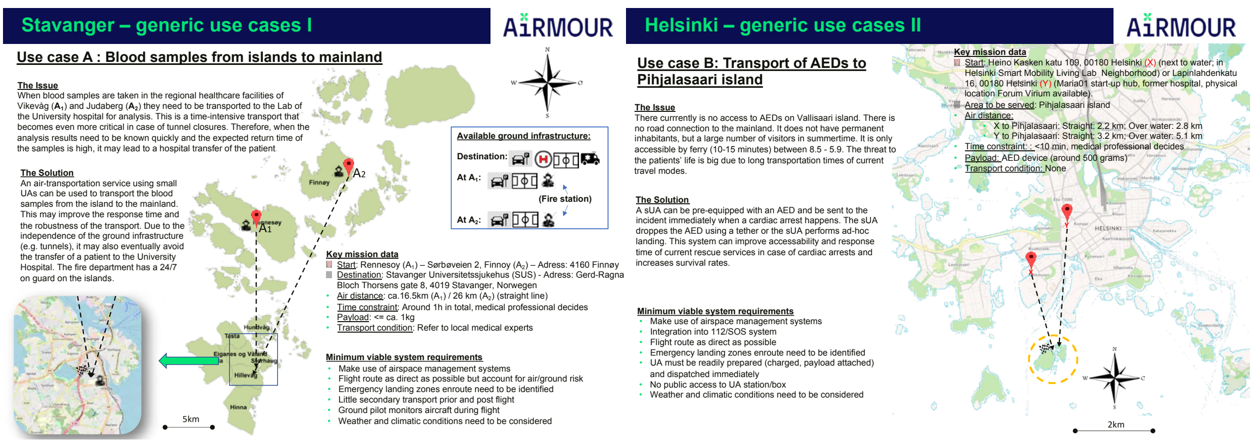


Figure 3: Use case examples for remote areas.

The document “Functional requirements for selected manned and unmanned UAM EMS scenarios” is available for download here.

Interaction and integration of UAM

Emergency medical services remain among the most acceptable services that could be provided by UAM. However, concerns such as noise and privacy (see below) are still high. The integration of UAM EMS is about increasing EMS chain efficiencies and, possibly, the equity of care (rural vs. urban). It is not about environmentalism and congestion reduction.

Due to local characteristics in terms of geography, existing medical system and political priorities, there is no one-size-fits-all approach for the penetration of the EMS by the UAM industry. The AiRMOUR deliverable 2.3 describes a generic framework looking at three phases, i.e., ‘Explore’, ‘Analyse’ and ‘Implement’. Each phase is supported with practical To-Do items for the reader. The framework is addressed to local stakeholders, mainly EMS stakeholders, research organizations and authorities:

- The ‘explore’ phase can lead to the creation of One-Pager documents that summarize local use cases and that can be used as presentation and discussion tools to better engage stakeholders.
- The ‘analyse’ phase may use simulation tools to objectively understand and measure the value of an UAM EMS service. Qualitative tools (e.g., SWOT analysis, Business Model Canvas, flowchart diagrams) involving local stakeholders are recommended as well.
- The ‘implement’ phase recommends a phased integration process from small-scale demonstrations to regular operation in order to enable a learning curve and to keep the overall risk manageable.

The next part of this document relates extensively to the integration of UAM.

The document “Report on the effects of interaction and integration with other EMS transportation modes” is available for download here.

2: Safety and regulatory requirements

In a nutshell:

Urban Air Mobility is guided by a fast-evolving set of aviation rules, set at the European level, and implemented nationally. Some are already published but many of the regulations are still under development. Most cities currently have a limited say in the implementation of aviation regulations, yet they need to understand them to make informed choices regarding urban air mobility.

Urban and spatial planning regulations vary significantly from country to country and remain largely detached from aviation regulation. Therefore, consolidation of the interaction between aviation and urban regulations are necessary to do on a local level.

Air and ground risk mitigations for UAM flight operations are demanding and each flight operator must receive approval for their missions by the civil aviation authorities. Therefore, urban authorities can focus on questions such as service networks, social acceptance, environmental aspects, and integration with other transportation modes.

Landings at ad-hoc (unprepared) locations are currently performed by highly trained professionals piloting helicopters and may not be possible to do in the same way with drones and eVTOLs. However, many solutions exist to lower a payload from the air or fly to pre-approved locations.

The risk should never be seen as a single element but rather always broken down into a likelihood of an occurrence that has a potential impact, may that be financial, human, legal, reputational, short or long term, environmental etc.

As can be intuitively conceived, an event that has very negligible consequences does not need to be prevented as much as one that would trigger harder consequences. Resulting from the above, the need to prevent a risk will always articulate around the reduction of probability combined with contraction of impact. The former may be gained from the redundancy of systems so that one takes over should one fail. This type of redundancy is typically present in multirotor vehicles. The latter may take the form of parachutes to slow down a drone that would be out of control or having a person on the ground to mitigate the risk of a landing.

As with any developing technology and regulations, it may be expected that some regulations will be clarified through jurisprudence.

	A - Catastrophic	B - Hazardous	C - Major	D - Minor	E - Negligible
5 - Frequent	5A	5B	5C	5D	5E
4 - Occasional	4A	4B	4C	4D	4E
3 - Remote	3A	3B	3C	3D	3E
2 - Improbable	2A	2B	2C	2D	2E
1 - Extremely Improbable	1A	1B	1C	1D	1E

Figure 4: Typical risk matrix.

Different legal frameworks

UAM operations are regulated by rapidly developing European aviation regulations. City planning, on the other hand, is usually regulated regionally or nationally based on decades if not centuries of local development, enriched by cultural differences, geopolitical influences, and environmental adaptation, directed by national standards, with local variations driven by local politics. So far aviation and city planning regulations have not been seen as linked. The role of a region or a city related to aviation has been limited to questions of land use, environmental permits and building permits.

The new U-space regulation related to automated UAS traffic management is the first regulation to formally invite non-aviation stakeholders such as cities to be involved in the establishment and monitoring of pieces of airspace. Indeed, UAM regulation is currently in its infancy and will evolve as the technical and technological developments emerge. Cities and regions will have to date little concrete possibilities to influence them. However, with the advent of UAM, it is only likely that cities become active stakeholders in the management of the low-level airspace and the supporting ground infrastructure. The EU commission's Drone Strategy 2.0[5] published 12/2022 outlines: *"52. Local communities, cities, regions have a deciding role for ensuring the alignment of Innovative Aerial Services with the needs and preferences of their citizens. They have a key role in deciding to what extent drone operations can be conducted in their territories. For example, they are in a good position to assess which critical infrastructure should be protected, whether operations should be allowed in day or night-time, what should the measures in place be in terms of noise and visual abatements. […]"*

Also, medical regulations are mainly harmonized at the European level and offer a high level of maturity, even if the regulations on EMS services vary from country to country. Medical regulations are often a mix of local methods, processes, and international regulations. They all offer different stages of maturity, harmonization and, therefore, challenges:

Field of application	Maturity	Harmonization	Challenges
Aviation	High	Advanced	Applicability Scalability
Air Mobility	Low	Ongoing	Responsibility vs. Accountability Understanding of rules Technical feasibility
Urban Mobility	High	Low	Actual engagement Feasibility
Medical	High	Completed	Complex in itself
Others	Medium	Low	Energy/governmental/taxonomy/RF

Table 1: Maturity of various regulations.

While most city officials will not need to dive deep into aviation nor medical regulations, it will be necessary for cities and regions to understand which regulations affect UAM and by extension the city.

The AiRMOUR project has published a table of the regulations that apply to the medical emergency situations served with aerial drones and gaps that currently exist. While UAM regulations are being developed, they are inherited from aviation rules. As such, the transport of blood, subject to many regulations from the medical sector may also fall under aviation rules specific to what would be considered “dangerous goods” in the aviation sector, therefore subject to particular procedures.

The document “Overview of legal environment for EMS scenarios” is available for download here.

Air Risk

Managing air risk is the responsibility of UAM operators, based on rules imposed by EASA or the local Civil Aviation Authority.

Aviation’s “Safety first!” cornerstone principle makes studying air risks central to UAM applications. To ensure flight safety, manned aircraft in Europe must follow the Standardised European Rules of the Air (SERA) as laid out in regulation (EC) 2018/1139. Naturally, drones are required to keep well clear of manned aircraft.

The analysis of air risk focuses on collisions with people-carrying aircraft, which are assumed to always be catastrophic with potential loss of life. As with all events with a catastrophic outcome, accidents looked at under "air risk" are therefore considered as ones that should be avoided at all costs. Mid-air collisions between air vehicles without people onboard, for example logistics drones, would be considered through the lens of the ground risk resulting from the falling debris. It is therefore outside the scope of air risk management.

Likelihood of fatalities to third parties in the air =

- 'Aircraft encounter rate' multiplied by
- 'Likelihood of strategic mitigation failing' multiplied by
- 'Likelihood of tactical mitigations failing'.

The analysis of air risk therefore lies with the encounter of an unmanned aviation vehicle with another unmanned aircraft carrying humans, with birds or with manned "regular" aviation.

Manned aircraft are normally not allowed to operate below 150 meters above ground except for take-offs and landings. However, some helicopters and military aircraft operate also below 150 meters. In addition, manned aircraft may occasionally err into the very low-level airspace below 150 meters above ground, especially in terrain with significant height differences. Relevant to UAM EMS applications, HEMS helicopters routinely fly below 150 meters and operate at the same hospitals that UAM EMS aircraft are expected to serve.

By utilizing publicly available historical flight data for commercial air traffic, it is possible to quantify the air risk and provide both air risk maps and expected fatality rates for specific UAM missions. The case studied in the AiRMOUR deliverable on "Air Risk" focuses on the area around Stockholm (capital of Sweden) and the examples provided are just rough estimates based on commercial flights. However, the methodology is applicable for any city and level of detail. The analysis shows that the air risk originating from commercial air traffic, as expected, is quite low for the altitude level where UAM EMS are likely to operate. However, for future real operations, it is vital to complement this with data for other types of conflicting traffic, like helicopters and general aviation.

Moving forward, AiRMOUR recommended that EASA should require all aircraft (manned or unmanned, powered, and unpowered) operating below 150 m above ground level (AGL) or even higher to be electronically conspicuous with the only exceptions:

- Security classed operations, which need to be able to operate on their own risk.
- Operations at pre-designated locations, e.g., model aircraft at model airfields, parachuters at known parachute fields, etc.

The document "Air Risk Management for UAM EMS operations" is available for download here.

Ground risk

Ground risk is the risk posed to people and critical infrastructure on the ground as a result of an uncontrolled landing or crash, or of the payload landing uncontrollably. Damages resulting from a collision with a bird, another UAS, the ground or from system malfunctions all create ground risk. Therefore, the aviation authorities require sufficient ground risk mitigation along the whole flight route, including take-off and landing.

Ground operations and landing site management

Through interviews with operators providing EMS with aircraft that hover, take off and land vertically in urban or other environments where there may be people, we have established a baseline understanding of ground risk management for EMS air operations. The risk at landing site can be divided into three types of risks:

- Direct risk to the vehicle is particularly high when operations occur at a non-certified landing area. In that case, pilots rely extensively on experience and multiple crew members to lower the risk. The crew scans for direct risk but also indirect in case something blown away hits the vehicle.
- Direct risk to involved parties, also particularly high when operating off base is essentially related to a) the vehicle hitting something and b) something blown away by the vehicle hitting something and c), someone approaching the vehicle and hit by moving parts.
- Indirect risk between third parties. This risk has been highlighted as operations, mostly off base, which may distract the attention of drivers of bystanders.

As one can tell, the risk of operations is significantly higher when operating outside of pre-approved landing sites. In that sense, the ground risk in operations with drones is partly similar to those in EMS operations by helicopters (HEMS) but they are also different.

In many cases, the multi rotor structure will provide an increased ability to hover (fly stationary) although light drones or UAS with fixed wings may be comparatively more sensitive to wind.

On the other hand, the downdraft of aircraft benefitting from distributed propulsion or from smaller drones may be significantly lower than that of helicopters, therefore lowering the risk of debris or objects being washed away compared to helicopter operations.

Ground risks may be reduced if landing sites meet certain prerequisites, such as:

- Ground paving, rather than compacted soil or gravel;
- Absence of protruding obstacles, such as poles, plants, buildings;
- Absence of loose objects, like bikes, furniture, tents;.
- Wind indicators if the area is enclosed by a fence.
- Landing zone markings on the ground;
- Enough cleared space around the landing zone.

The typical ground risks identified by and relevant for HEMS operations must be evaluated by drone operators and experts in UAM to identify which risks are valid for UAM. Several methods exist to quantify the risk. Most drone operations will be referring to a Specific Assurance and Integrity Level “SAIL level” in reference to the Specific Operations Risk Assessment (SORA) while any human carrying operations will be assessed with methods close to those of helicopter operations.

In March 2022, the EASA published the “Prototype technical design specifications for vertiports”, the first set of its kind of prototype common requirements for landing sites, for human-carrying vehicles that take off and land vertically; so called vertiports. Those vertiports along with the Final Approach and Take Off areas (FATO) and approach volumes will be able to take different dimensions for different aircraft and offer different levels of services (hangar, charging, passenger management, etc.) possibly in different conditions (low visibility, night etc.).

The document “Ground Risk and landing site Management” is available for download here.

Adjacent infrastructure and technology

Currently, there is little standardisation in how UAS interact with ground infrastructure whether physical or digital. For example, small logistics drones may be able to winch their cargo down to the user or land on small pieces of land or even rooftops. Larger drones will require specific infrastructure, for the take-off and landing operations as well as supporting activities, (passengers and cargo security, boarding and loading operations, etc.). Moreover, batteries will be either swapped or charged.

Scaling up UAM is reliant on reliable digital connectivity throughout each flight and between flight operators. Drones are basically machines in the air that need to communicate with machines on the ground handling drone traffic control. In Europe, the concept of drone traffic management is called U-space. The concept of U-space was established in 2017, where “U-space is a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones.” (SESAR Joint Undertaking, 2023).

On January 26, 2023, the first new European regulation (EU) 2021/664, 665 and 666 on U-space airspace was published enabling establishing certain parts of the airspace into U-space airspace, where a subset of the complete U-space vision can be implemented as a first step towards enabling missions BVLOS without overly restricting traditional aviation and enabling several BVLOS missions from different drone operators to coexist in the same airspace.

In U-space airspace:

- Drones have to keep sending their position and identity to the U-space system while they fly.
- Drones need to have an approved and activated flight authorisation (“flight plan”) before they can take off. This flight authorisation ensures that there are no other conflicting drone flights planned, and the authorisation can be withdrawn to avoid risk of collision with manned aircraft.
- Drones must report any contingency or emergency condition, that may lead to them violating the conditions in their flight authorisation and become a risk to others.
- In controlled airspace air traffic control must temporarily close U-space airspace if manned aircraft needs to fly through (for example a rescue helicopter). In uncontrolled airspace manned aircraft must make themselves electronically visible to the U-space service before entering U-space airspace. This can mean extra costs for the manned aircraft operator.

Initially, U-space airspace is expected to be limited to heights below 150 m[2] and established in airspace where the risk of encountering manned aircraft is low. This limitation is considered necessary to ensure safety of operations in the U-space airspace across the EU as the present status and maturity of the technical U-space solutions are still evolving rapidly.

The U-space regulation and its article 18 (f) is the first regulatory artifact supporting a broader role of cities in the management of the low-level airspace. Article 18 (f) says: *“The designated competent authorities shall (f) 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 unmanned air systems (UAS) within that U-space airspace and the determination of the U-space services to be provided in the U-space airspace;”.* The aim of the coordination mechanism is that the designated and deployed U-space airspace fits the regional and local well-being needs, local traffic infrastructure and complements it (e.g., without hindering other traffic users such as pedestrians, cyclists, and means of public transport).

Cybersecurity risks

The risks related to cybersecurity are mostly related to the infrastructure of the drone or the related systems. The information that is funnelled around concerning the mission of the drone may be accessed by unauthorized third parties, possibly altered. The integrity of this data is particularly critical in the context or EMS.

During operations, the mission critical information of the air vehicle, possibly the information that is obtained by the on-board sensors and cameras may be accessed and altered by unauthorized third parties. The preservation of this data is equally important.

2 UAM traffic is expected to mostly be limited to heights below 120 m above ground, leaving at least a 30 m vertical safety buffer between manned and UAM traffic. However, for airspace planning purposes, it is necessary to consider the whole Very Low Level (VLL) airspace up to 150 m above ground level.

Different technologies, as well as countermeasures are possible and covered in the additional reading in the hyperlink box below.

Cybersecurity concerns

There are currently no standards in place for dealing with cybersecurity issues in drones.

Multiple papers[6] have shown that most components of a drone system (flight controller, sensors, GNSS receiver, communication channels, ground control station (GCS), cloud services etc.) are likely to be targeted by cyber-attacks. These weaknesses have now been understood by manufacturers and most of them have thorough programmes in place to increase the cybersecurity.

Redundancy of systems and the experience of pilots are a backup that may help lower the likelihood and impact of a cybersecurity breach.

The “Report on cybersecurity threats for the EMS scenarios” is available for download here.

3: Socio-economic impacts

In a nutshell:

AiRMOUR deliverables show that the social acceptance is generally higher for urgent medical missions and for flights in commercial areas of a city compared to flight in residential areas. Cities will be the partner of choice to interact with citizens and to manage complaints. Cities should therefore prepare to inform citizens about how they can influence the development of UAM traffic.

People who have attended drone presentations seem more positive towards drones afterwards than before. By extension, there is reason to believe that the actual level of social acceptance for UAM services will only be understood once citizens get exposed to and benefit from them.

UAM service design must understand the relevant stakeholder groups in order to create an efficient communication process to facilitate social acceptance. Communication may be enhanced with the support of data, including geospatial information, where service areas and local considerations can be clearly marked. An active communication strategy may be needed, especially when launching new services including methods such as workshops, surveys, and masterclasses to improve the awareness among the population of the new services.

Map of stakeholder groups

By “stakeholder group”, we refer to a collection of individuals and/or organizations, with similarities, whose actions or role may be impacted in a similar manner by the deployment of urban air mobility.

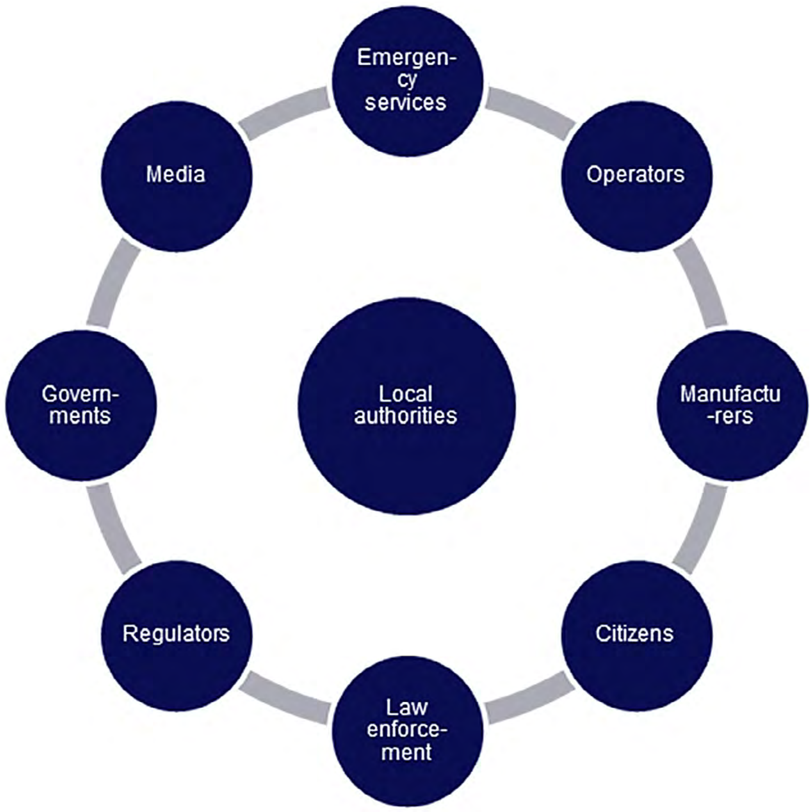


Figure 5: High-level stakeholder groups.

Local authorities

Local authorities are, along with operators, the core stakeholder group and target audience of this guidebook. They represent a large and very heterogeneous group of departments with interests that may be conflicting and should be balanced between short-term goals and long-term objectives. They are well represented among AiRMOUR's partner and replicator cities and will likely either define or participate in local communication plans to engage other stakeholders.

Throughout history, cities have been holding as much population as the land around them could feed within 2 days of transportation. As transportation was revolutionised in the 20th century, the size of cities skyrocketed. However, with the coming reduction of dependency on carbon-based energy, cities will yet again face changes and have to envision a different organization given increasing transportation costs and consider concepts such as 15-minutes cities.

Emergency services

UAM as studied in AiRMOUR, used for emergency services will affect those stakeholders particularly. Emergency services may enhance city capabilities by adopting UAM as a complement to existing emergency-response fleets and personnel. New roles will be created, needing new types of training as well as resource reallocations. AiRMOUR's work indicate that the adoption of UAM will require additional resources in the short term.

Operators

The operators as a stakeholder group cover those providing current emergency services (including helicopter operators and ground taxis). Incumbent service operators will be affected by UAM EMS services. Besides new investment requirements and organization changes needed to provide the new services, the operators also naturally carry responsibility for the safe operation of the flights and for integrating the new UAM EMS capability into the existing service network.

Service operators may become natural allies to cities to help answer questions from citizens and to bridge the knowledge gap about aviation in urban environments. The cooperation between operators and city officials may be particularly rich as local or regional authorities have little legal ground to influence where operations take place. The development of UAM-enabled service production and by extension service operators will mostly be driven by procurement conditions and the allocation of public funds to developing the UAM ecosystem. Service operators of the new UAM service have to obtain flight rights and operational authorizations from the aviation authorities. Additionally, depending on the national legislation, city planning regulations may limit where flights take place and landing areas are established.

Drone Manufacturers

Drone manufacturers have worked for over ten years and collectively raised billions of euros to develop the technologies underlying UAM. They are therefore under pressure from investors to find viable use cases and eager to cooperate with cities and operators. In some cases, manufacturers will undertake to operate pilot flights, but only few manufacturers wish to remain in an operator role. Before UAM, the drone industry was heavily vertically integrated, with an increasing number of specialist drone platforms that are deeply integrated with supporting software to drive end-to-end operational efficiency and effectiveness. The same development should be expected in UAM, where those few manufacturers, who focus on the full bundle of components to enable UAM EMS service production will dominate. Even though more than 200 companies have come up with UAM vehicles eligible to fly in the urban environment, only a few target EMS service production for EMS use cases with too many manufacturers only providing flying platforms.

Generally, there are two reliability levels of drone systems involved with professional activities. Cargo-drones will mostly fall into the 'specific' category of aircraft and need to demonstrate to aviation authorities a level or reliability (airworthiness) that is proportionate to the risk profile of the mission. Such demonstrations of airworthiness include both software and hardware and may require thousands to test flight hours. Any human-carrying aircraft will need to be type certified, which typically costs tens or hundreds of million euros and takes several years to achieve. Therefore, it is reasonable to expect that UAM EMS aircraft will be supplied by manufacturers who have the financial resources to build and test for years before receiving any income. Additionally, to make UAM aircraft cost-efficient, the costs of this rigorous testing will, by necessity, need to be offset by each manufacturer selling large volumes of their UAM systems. According to partners in Stavanger, it is expected that the market for human-carrying UAM EMS vehicles will consolidate around a small number of capital-rich manufacturers.

Citizens

Cities are at the forefront when it comes to understanding their citizens, their differences, common goals, and contradictions. Mobility solutions always need to be adjusted at the local level. However, many biases threaten to distort insights when collecting the voice of the citizens and addressing their concerns. Some categories of population are likely to benefit more than others from the deployment of UAM.

A consistent finding, presented at Amsterdam Drone Week 2023, was that “citizen engagement” is the key to gaining acceptance for UAM. Studies, including those presented below, carried out on the attitude of citizens have shown that there is a higher level of acceptance for the use of unmanned aircraft in emergencies compared to commercial applications. Surveys and workshops also disseminate information about new services as well as engage a representative sample of citizens.

Law enforcement

Law enforcement representatives typically have two parallel types of concerns. On one hand, law enforcement benefit from using drones for surveillance or monitoring purposes. On the other, they will be on the frontline to make sure that regulations are adhered to, and that ignorant or malicious use of drones is detected and demoted. In both cases, law enforcement agencies wish for a very structured and fail-safe development of air mobility regulations and operations, which may possibly slow down the deployment of UAM solutions.

The participation of law enforcement agencies in workshops and other communication efforts will help them to understand the benefits as well as threats introduced by UAM EMS services.

National and Regional Governments

The governing of public infrastructure and proposing environmental laws often fall under the jurisdiction of national or regional governmental bodies such as ministries or transportation authorities. Their impact guides the decision-making process and therefore the choices that cities make with regards to transportation. It is important to notice that there is a lot of variability in how countries define the role that their national or regional governments have in their societies. Irrespective of the precise role, it is important for cities and regions to maintain a relationship with the national governmental bodies and influence their opinions to reflect the needs of the city or region.

Governments officials have a large role to play in the choices related to infrastructure but also have an intermediary role between European level decision making and local one. Consequently, the participation of national authorities will enrich the workshops by their transverse understanding, and they need to balance the decisions between various priorities.

Civil Aviation Authority (CAA)

The CAA is responsible for both implementing the new UAM-related regulations, which have been set by EASA (European Union Aviation Safety Agency), for implementing nationally regulated state aviation rules, for managing the airspace including flight restrictions (in some countries handled at Ministry-level) and for delegating air traffic management to approved service providers in your region, and for issuing flight authorisations to Service Operators.

UAS geographical zones are an airspace structure that can enhance or restrict the use of drones in a portion of the airspace. These geographic zones are one of the key legal tools for a city and region to control UAM in parts of the airspace. Their applicability varies from country to country, so local dialogue between the city and the CAA is essential.

Media

The media, whether local or international, paper or online, traditional, or new, has the power to drive crowds, influence minds, and spread ideas. Over the last decade, the media world has lived by two trends: shorter messages and polarization. In the context of development of urban air mobility, the media will have significant power to both inform people and to shape opinions.

It goes almost without saying, that media should be tightly and proactively included in workshops and other communication activities.

Public acceptance is about trust, benefits, limited adverse impacts and integration

Public acceptance of a new technology depends upon trusting its capabilities and safety, demonstrating the benefits for society, minimising adverse impacts while maximizing the positive externalities, and about working towards a smooth integration into the current service network. People’s trust in new technologies, such as UAM, is at first linked with how safe it is perceived to be. People trust and expect that their local government will ensure that new technology is guaranteed to be ‘safe’ before it is made publicly available.

People who live close to a vertiport and who do not use private eVTOLs that land or take off there, are expected to be much less willing to accept the new service than people also benefitting from it. Therefore, the placement of infrastructure needs to be carefully planned in coordination with the respective citizens to reduce the adverse impacts and complaints from the residents. Linked to public benefit is also how well UAM can be integrated into our cities and into the existing transport network. It is important to identify issues and gaps in the current transport systems and reduce negative effects, such as air pollution and lack of accessibility.

The media plays and important role in influencing public opinion, which can either help support or hinder the progression of UAM. One such example is the London Gatwick airport (UK) drone incident where two unidentified drones allegedly flew into the runway airspace and caused hundreds of flights to be cancelled over three days. The sightings were never verified, yet the media picked up the story which caused great concern for the public around safety and privacy issues of drones. On the other hand, a drone carrying a defibrillator recently saved a life in Sweden, which received a lot of positive press and increased public support as a result.

Typically, a negative experience is shared in the media more than a positive one. The perceived risk is influenced, for example, by facts (e.g., number of fatalities per X number of flights), anecdotes (e.g., family members have used the technology and think it is safe) and personal experience (e.g., comfort experienced when using the technology).

It is recommended that cities take a proactive approach to engage citizens, for example, by forming a citizen advisory panel and by publicly conducting attitude surveys for which the results are published, discussed, and the feedback demonstrably considered in UAM service design.

Mapping citizens' thoughts without bias

As reported in some studies and from AiRMOUR consortium interviews with industry experts, the greatest concerns regarding UAM by the public are anticipated to be safety, privacy, and noise impacts. AiRMOUR paid specific attention to identifying biases in questionnaires, as there are rife examples of biased surveys, for example conducted at trade events, which would only get responses for people who are already interested in the topic. Multiple studies on neuroscience exist on how inherently biased we are to answer a neutrally phrased question[7].

Of the mistakes that have been made in recent studies performed for UAM, we have identified the following common mistakes:

- **Asking closed questions for topics that cannot be answered by yes or no.** Questions such as "Do you know Urban Air Mobility?" cannot be answered by a yes or no answer. In this case, it is unclear are we asking if people know the words, the capabilities, or the technology. An improved way here would be to specify the question and offer multiple choice answers, such as *"very well, fairly well, etc."*. This is, however, far from perfect, as self-assessment is biased per person but also varies per gender and culture. A study released by the American Automobile Association in the US showed that 73% of US drivers saw themselves as above average drivers. In the same manner, the area and level of expertise of possible experts that may be interviewed should be understood thoroughly by the interviewers.
- **Use of leading phrasing.** As reported in Bloomberg, the phrasing of issues contributes highly to how said issues are seen, how the responsibility is allocated, and how people engage with it. Phrasing a question towards the benefits that the drone technology offers will always bring more positive results than phrasing them around the negative. A question such as "How likely are you to make use of delivery by drone", even with the detailed assumptions regarding price and time will necessarily bring more positive answers than "How likely are you to support your neighbour's drone delivery". This bias is a precursor of what the Anglo-Saxon world refers to as NIMBY. Not In My Back Yardism is a characterization of opposition by residents to proposed developments in their local area, as well as support for strict land use regulations. It carries the connotation that such residents are only opposing the development because it is close to them and that they would tolerate or support it if it were built farther away.
- **Skewing results.** Nobody in their right mind would proceed to the All England Club in London during the Wimbledon tennis tournament to obtain an unbiased representation of the opinion of people about tennis. However, it is frequent to bring a drone to a place and ask the citizens gathering around it of their opinions about drones. Naturally, only people interested in the drone would have stopped to look at it. Therefore, the people selection would be skewed.
- **Leading questions**. Questions may also be leading. *"Which of the below medical emergency use cases would you consider the most useful in an urban environment?"* will lead the respondents to see value in something that they would not otherwise have considered.

AiRMOUR produced the most extensive public and stakeholder survey on the topic of Urban Air Mobility (UAM) and drones in Europe since EASA's study published in May 2021. The engagement activities included a European citizen survey circulated in six countries (Norway, Sweden, Finland, Netherlands, Luxembourg and Germany). Interviews were carried out as well as a technical stakeholder survey and a technical stakeholder workshop. The demographics of participants were broad to gather a good representation of societal views. Focused discussions with stakeholders were carried out on the topics of public acceptance, safety and risk, privacy, socio-economic impacts and environmental considerations.

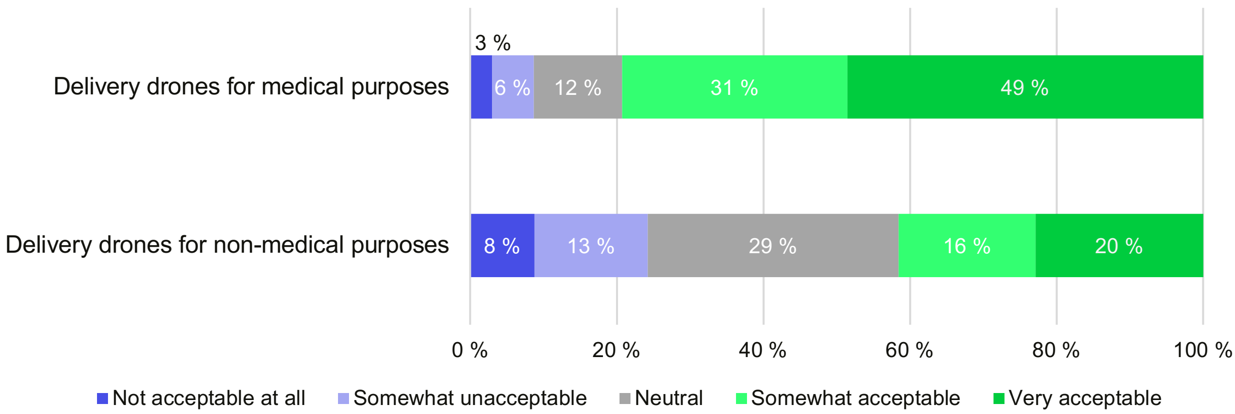


Figure 6: Acceptability of medical vs. non-medical use.

A Summary brochure and details of the Public and stakeholder acceptance report are available here.

Mitigating the effects of noise and visual pollution

Different stakeholder groups may perceive the newly created visual and noise pollution differently. It is likely that cities will be the first to hear when citizens wish to voice their concerns about noise or visual pollution created by drones. The data collected by partner Linköping University show no noticeable difference between Germany, Norway and Finland in how people consider noise and visual polluting from drones.

How many people are exposed to the nuisance may also vary. Urban Air Mobility was imagined with an idea of using the skies freely. However, as shown in other parts of this document (for example chapter 5), multiple areas should not be overflown, unless the ground risk is properly mitigated, for strategic (state security, critical supply) or social (schools, daycare centres) reasons among others. There are therefore two fundamental philosophies coexisting. Should authorities decide:

- Where to fly and create “highways of the sky” also known as corridors where the traffic would be concentrated or
- Where not to fly, thus leaving it up to service operators to optimize their operations outside of the prohibited or restricted areas.

Both have advantages and disadvantages. The findings of Linköping University show that, although the perception of pollution increases with the number of UAM flights and decreases with the distance of the observer, the relationship in not linear. The University finds that adding an additional flight in a busy flight environment is perceived as less polluting than an additional flight in a quiet environment. From this observation, the university recommends that, should corridors be created, the traffic could be concentrated so that few are exposed to the nuisance.

Corridors could be created, balancing the risk (air and ground) with the nuisance (noise and visual) to optimize the outcome. The results show that UAM flights should not be planned in isolation since they affect each other, most clearly through the need for conflict resolution when they get too close to each other. Relying on individual flight path planning and ad-hoc conflict resolution might be sufficient from a risk perspective, but may increase the noise and visual pollution, as well as the average path length. The results furthermore show that the trade-offs between the different objectives are not straight-forward. For instance, routing two drones away from highly populated areas, making them fly close to each other, might reduce the risk for fatalities as there are less people on the ground who might get hit by a drone out of control, but it may also increase the risk since the probability for a collision increases. Moreover, the noise pollution experienced on the ground might decrease when flying over sparsely populated areas, but when the drones are close to each other, the joint noise pollution from the two vehicles might be regarded as annoying, even if the noise from one single drone would not be. For visual pollution however, the results seem clear; it is in general better to cluster drones, e.g., to have them flying in corridors, than having them fly freely.

To add to the complexity, the expected UAM traffic will be quite diverse with regards to reliability (airworthiness) and urgency of missions. Emergency Medical deliveries with drone systems having the same level of reliability as commercial manned aviation may coexist with commercial goods deliveries and with human carrying eVTOL flights. Some of these flights may safely fly over schools and other sensitive areas, some flights may be on life-saving missions and not have the time to follow corridors, whereas some flights may not have sufficient reliability (airworthiness) to be routed along corridors with high ground risk. Therefore, it is imperative that any authority engaged in planning flight restrictions, is well versed in the details of the emerging UAM industry, so as not to inadvertently create strategic blockers for the industry and by extension obstacles for better serving the society.

Linköping University however highlights that results may be interpreted with caution as extrapolation from a single flight and a small audience can hardly be extrapolated.

The document on noise and visual pollution is available here.

Respecting citizens' privacy

Privacy is defined by experts as the "right to be left free of interference". The notion therefore encompasses much more than data and needs to be apprehended in a broader context. However, making decisions is, in nature, choosing and therefore, creating some interference. Privacy in the context of urban mobility may be looked at under many angles.

The Privacy guidebook published in the course of the project is organized around ten (10) recommendations structured along all phases from ideation to initial studies to, when applicable, roll out. The definition of privacy is presented under the first recommendation. The perception of what is privacy, and therefore the acceptance of the services from the point of view of privacy, is likely to vary between countries, over time and along the learning curve of the stakeholders. For this purpose, some questions are left open. While the authors believe the question is relevant and should be answered, the answer belongs to the groups of people that will be locally exposed to a new UAM service.

The Privacy deliverable follows a ten steps path as listed below.

1. Align goals and boundaries internally: What is Privacy?
2. Map stakeholders and expectations.
3. Understand and agree on the scope and its limits.
4. Anticipate the foreseeable consequences.
5. Take time to address the concerns.
6. Determine the information you need…
7. And what you are leaving out.
8. Bring the vision to life.
9. Allocate roles and responsibilities.
10. Walk the talk.

The surveys conducted by the AiRMOUR consortium across the European continent show an overwhelming concern of the citizens for their privacy both from the use of cameras and from uncontrolled data sharing. It is possible that concerns will be reduced once respondents get to learn more about and experience the new services.

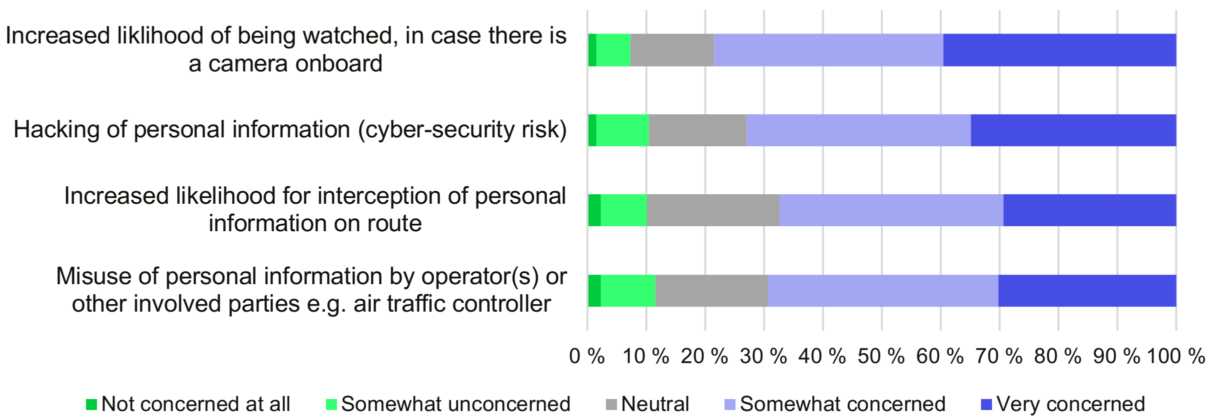


Figure 7: Results of the public perception study.

Whilst privacy encompasses much more than data, compliance with GDPR in also critical. During a flight operation, sensors may collect data to support the task execution and flight safety. The GDPR component of privacy in UAM operations is covered under Step #10 of the SORA yet little oversight is exercised. The GDPR imposes obligations onto organizations anywhere, so long as they target or collect data related to people in the EU. In particular, they address:

- Lawfulness, fairness, and transparency. The GDPR requires that the processing must be lawful, fair, and transparent to the data subject.
- Purpose limitation — You must process data for the legitimate purposes specified explicitly to the data subject when you collected it.
- Data minimization — You should collect and process only as much data as absolutely necessary for the purposes specified.
- Storage limitation — You may only store personally identifying data for as long as necessary for the specified purpose.
- Integrity and confidentiality — Processing must be done in such a way as to ensure appropriate security, integrity, and confidentiality (e.g., by using encryption).

The GDPR regulation does not require that one complies but that one is able to demonstrate that they comply. As drones are equipped with cameras and sensors, any operator should be able to demonstrate that the information picked up by cameras and sensors cannot be used to identify a person (anonymization at source and geofencing of any private compound or that they obtained consent from the subjects).

As the rules are either missing (for noise and visual violations) or those responsible for enforcing them are unclear about their relevance (for GDPR), cities should engage with their experts to clarify their exposure.

The document "UAM citizen privacy handbook" is available for download here.

4: Operational and environmental attractiveness

The CO_2 footprint of UAM is not always better than ground-based alternatives

A conceptual Life Cycle Assessment (LCA) model tailored to gauge the Cradle-to-Grave (from raw materials to scrapping) CO_2 impacts of UAM systems was created in the course of AiRMOUR. The study lays the groundwork for more sustainable urban air mobility solutions by identifying the key sources that influence the carbon footprint of UAM.

The study focuses on two UAS models: a small UASs for medical supply delivery and a medium-sized eVTOL aircraft for transporting medical personnel or patients. The proposed framework incorporates a sensitivity analysis module to account for the uncertainties prevalent in the respective domains.

The energy efficiency and CO_2 emissions of electric UAM concepts can vary when compared to other modes of transportation, depending on several factors. Specifically, it is essential to consider the type of vehicle (whether electric or fossil fuel-driven), route distance, and payload that can influence the outcome. For instance, under certain conditions, the small UAS may exhibit a larger CO_2 footprint than a diesel vehicle, and the mid-sized eVTOL may exceed that of a van, particularly in geographies with high carbon emissions to produce electricity (high grid intensity).

The findings reveal that emissions generated during the sourcing and production stage constitute a significant portion of the Cradle-to-Grave life cycle emissions of UAM vehicles. In particular, the production of electric motors emerges as the most substantial source of emissions for multirotor drones during manufacturing. As such, efforts to enhance the production efficiency of electric motors and reduce their carbon footprint are critical for improving the overall environmental performance of UAM systems.

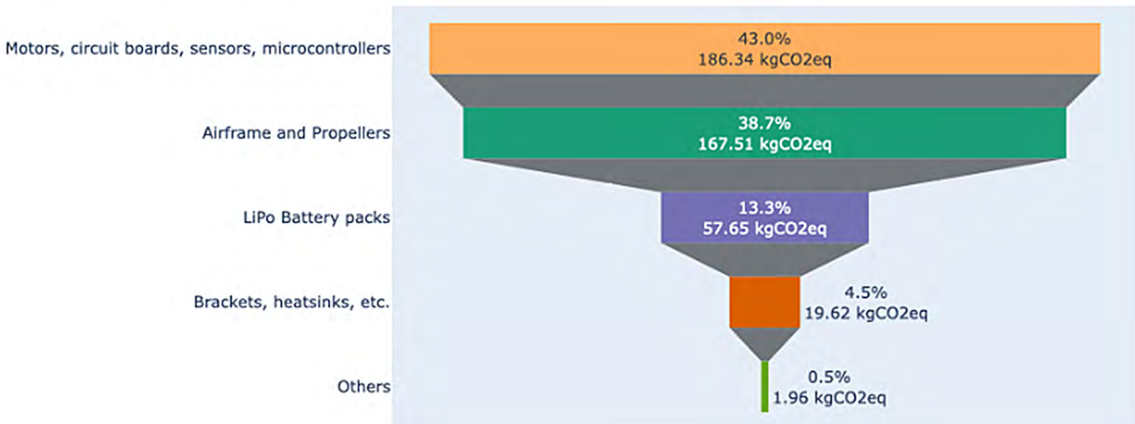


Figure 8: Cradle-to-Grave CO_2 emissions for the small (MTOM 17 kg) octocopter UAS in the study.

Additionally, the study highlights the importance of battery management in UAM operations. Frequent battery replacements magnify manufacturing emissions and increase resource consumption and waste generation. Addressing these challenges requires the development of more durable and efficient batteries, as well as the implementation of advanced recycling and disposal strategies to minimise the environmental impact of battery-related processes. Also, the operational patterns of flight systems, such as frequency and duration, significantly affect battery life and, consequently, the cumulative emissions generated during the battery's life cycle. It is imperative to evaluate the environmental impact of battery production within each specific use case, as flight operation frequencies influence the lifespan and associated emissions of these batteries.

The ground infrastructure of UAM also plays a critical role in determining the overall carbon footprint of UAM systems, and the sustainability levels of UAM infrastructure vary across different regions. This heterogeneity can be attributed to factors such as regional weather patterns, discrepancies in energy grids, and other context-specific elements.

Ground infrastructure network planning is a critical area of focus from an LCA perspective. The network planning and efficient logistics network design can help to minimise the environmental impact of UAM operations while maximising their utility and effectiveness. It is also possible to maximise the utilisation of the ground infrastructure through sharing facilities across multiple operators, optimising vertiport designs, or integrating UAM systems with existing transportation networks.

Climatic variations, such as temperature extremes and seasonal fluctuations, can impact the efficiency and operational capabilities of UAM systems. These meteorological factors may influence the energy consumption, range, and overall performance of aerial vehicles, as well as the demand for and resilience of UAM infrastructure. For example, an increase in the frequency of extreme weather events, including heavy rain, flooding, and robust winds, is likely to significantly influence UAM operations.

The study highlights the energy consumption of operating the ground infrastructure, particularly concerning heating, ventilation, and air conditioning (HVAC) systems in Northern regions. The low temperature in the winter seasons will drastically increase the power requirements for heating UAM infrastructure, underscoring the need for careful insulation and heat management strategies in ground infrastructure components such as automated UAS hangars. Conversely, the energy demand for cooling systems could escalate dramatically in regions with extremely high temperatures. Therefore, it is vital to design and manage ground infrastructure to ensure system reliability, withstand local weather conditions extremes, and minimise energy use, especially heating/cooling.

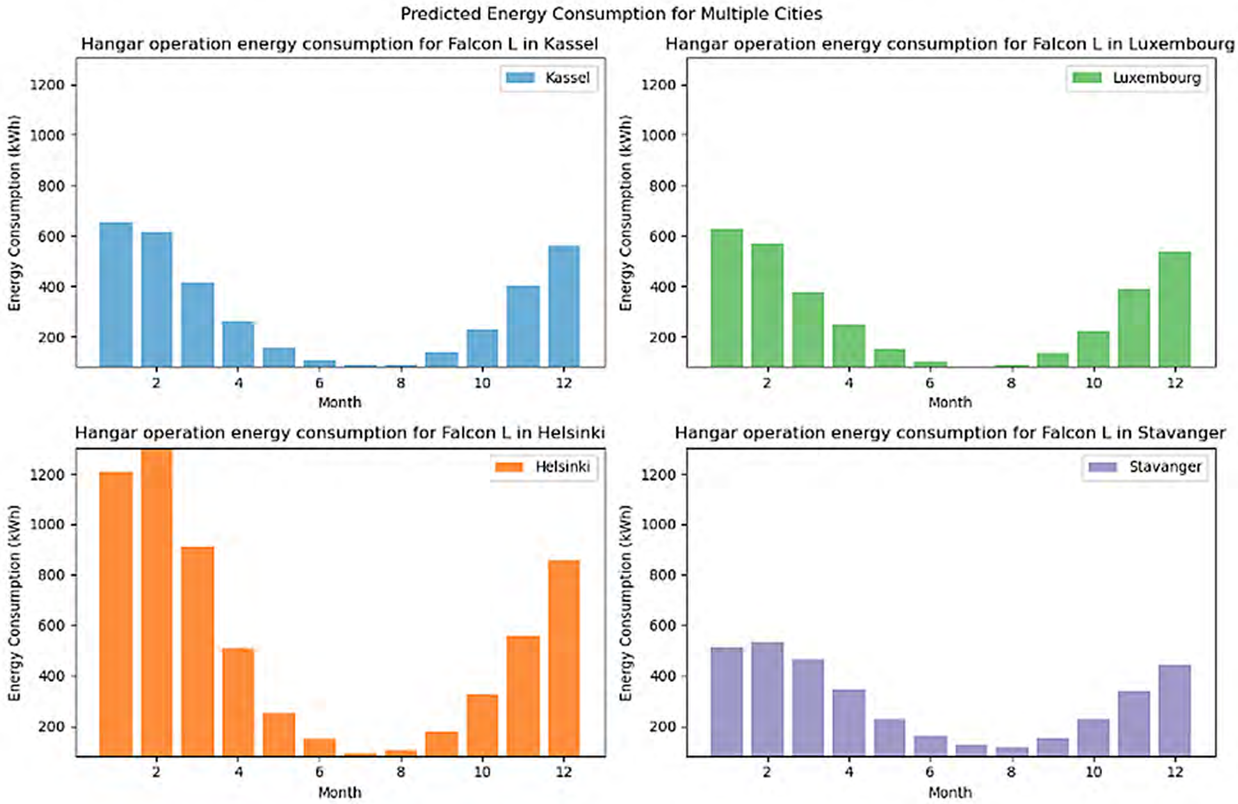


Figure 9: Assumed small UAS hangar operation energy consumption per calendar month for the studied geographies.

Moreover, regional disparities in energy grids contribute to divergent environmental footprints for UAM operations. The electricity mix, comprising renewable and non-renewable energy sources, directly affects the carbon intensity of UAM systems that rely on electric power. As such, regions with a higher proportion of clean energy sources will exhibit lower emissions and enhanced sustainability profiles.

For example, the Well-to-Wheel power consumption of the small UAS in the study is around 0.11 kWh/km with its maximum 5.5 kg payload. However, the Well-to-Wheel CO_2 emissions vary considerably due to the diverse grid CO_2 intensities in different countries. In Germany, which has the highest carbon intensity level of the four studied geographies of 553 g CO_2eq/kWh, the small UAS generates 74.4 g CO_2eq per package-kilometre travelled. Conversely, in Norway, with a carbon intensity of 41 g CO_2eq/kWh, due to the abundance of low-carbon energy sources, the UAS' emissions are significantly lower at 5.52 g CO_2eq per package-kilometre travelled (87% lower than Germany).

The sustainability measurement of UAM is faced with considerable uncertainties and should be measured based on specific scenarios, geographies, and time horizons. The sustainability of UAM operations depends on various factors, including vehicle type and size, load capacity, and the particular transportation delivery model employed. Addressing the question of whether UAM systems are more sustainable than other modes of transportation require a nuanced and context-dependent analysis.

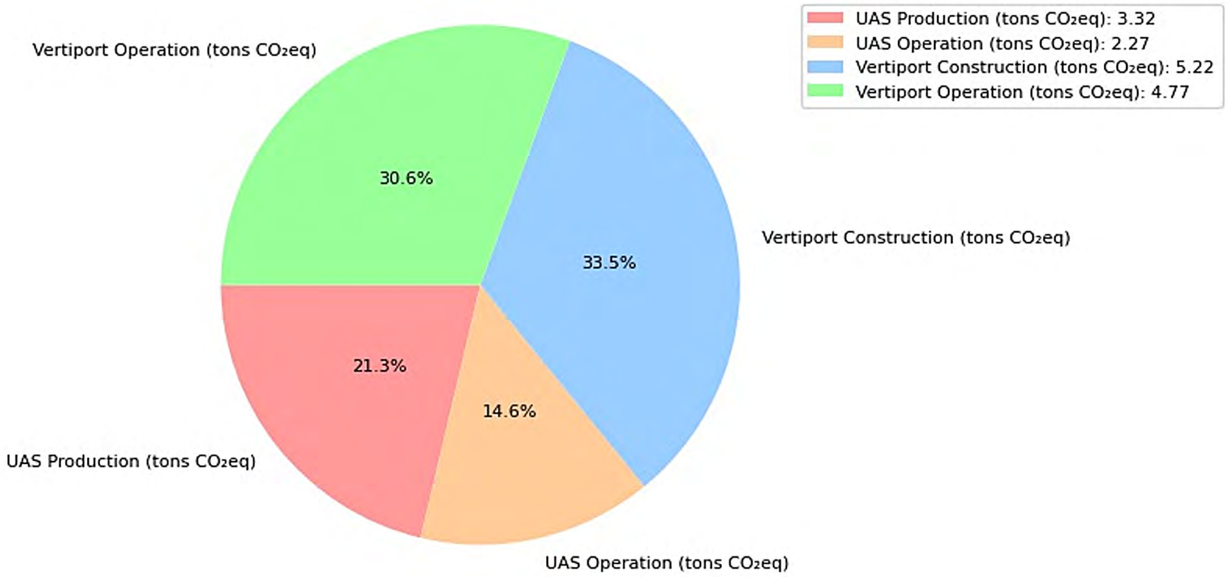


Figure 10: Total LCA CO_2 emission distribution for a small UAS assuming a 5% utilization rate.

It is challenging to compare UAM systems and other transportation modes due to the inherent differences in their characteristics and use cases. For instance, UAM systems may be more efficient and environmentally friendly for specific applications such as medical or disaster emergency responses but less efficient and less environmentally friendly for applications such as cargo delivery in urban transportation cases where cargo bicycles or personal electric cars may prove to be more sustainable options.

One aspect that can be definitively concluded is the crucial role of cleaner grid and energy sources in enhancing the sustainability of UAM systems and other transportation modes. The transition to vehicles and infrastructures powered by renewable energy sources can significantly reduce the carbon footprint and environmental impact of transportation systems across the board.

However, the allocation of batteries and other critical materials to the UAM industry will compete with decarbonisation efforts in other sectors. Therefore, the employment of UAM capabilities should be assessed in the context of holistic and Sustainable Urban Mobility Plans (SUMPs).

The document “CO_2 Life Cycle Assessment for Emergency Medical Service UAM Concepts” is available for download here.

Scalability analysis

The lessons learnt from cities participating in AiRMOUR are not transferable as-is to other cities, as the specifics of each city must be considered. The transferability and scalability of solutions to other UAM application areas was assessed in the project. Specifically, the task looked into the prerequisites for expanding and implementing UAM for EMS services, as well as other UAM services across European cities, and also for implementing the project in cities outside of Europe, specifically Dubai. The scalability assessment framework covers the technical feasibility, business viability and operational scalability. The three dimensions are evaluated through a set of questions shared via an online questionnaire directed at representatives for the cities and regions assessed, below referred collectively to as the “reader”. The responses are graded with the assessment framework into four distinct indices: City/Region Readiness, Business and Operational Scalability as well as a Sustainability Awareness Index.

The 50 questions are comprised of three types:

- Closed questions: The questions are used to invite the reader to take a stance. The answers are either in the yes-no format or offering multiple choices.
- Self-assessment scale questions: On a scale of 1–10 for example, the reader is invited to quantify their expectations.
- Open questions: Used by the evaluators to drill beyond the high-level responses and offer the responders to provide additional information or to provide more context.

The questions are phrased to require the reader to take a position. For example, a scale of 1–4 is offered rather than 1–5 to not allow a neutral “3” scoring. However, this choice induces a bias that the optimism or pessimism of the person taking the questionnaire may reflect a higher/lower score than a neutral assessment would convey.

The results should not be interpreted in absolute terms. Instead of comparing individual shipment routes, transportation networks should be compared. It should be noted that only one or two persons responded per city. As such, the results should be regarded as subjective, rather than objective.

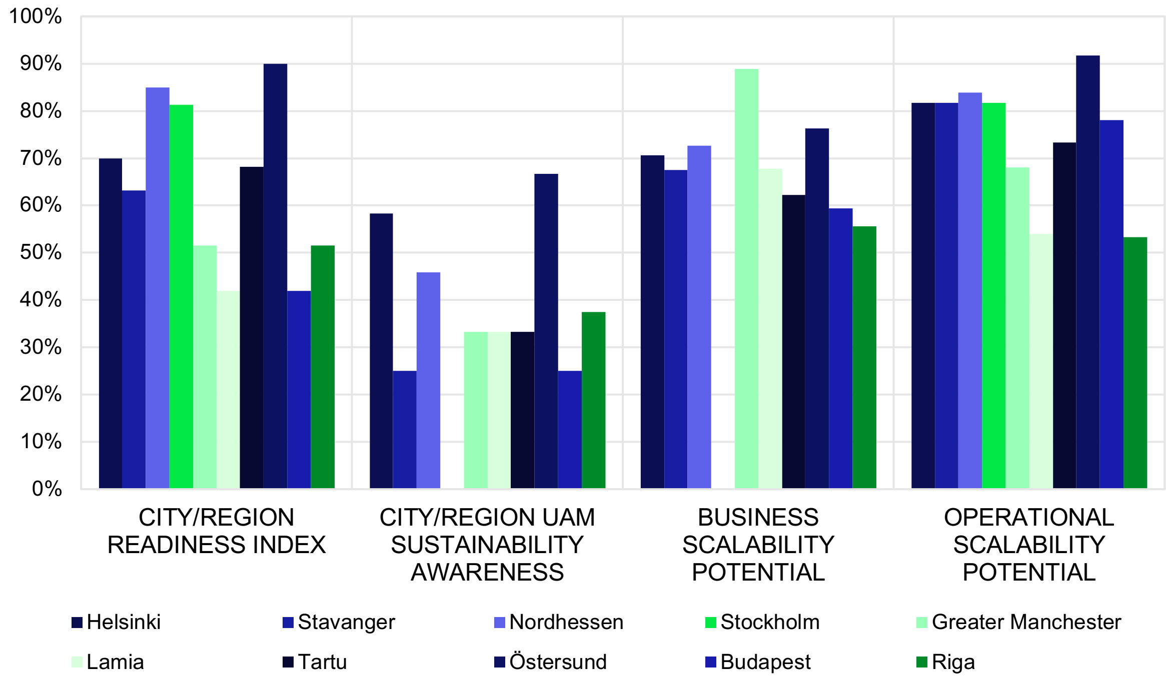


Figure 11: Scalability assessment results for ten cities.

Integration of UAM and business models

Despite the inherent complexity related to bridging urban planning and aviation topics, UAM may offer to fulfil some missions faster than ground transportation at a cost lower than those of a helicopter.

A survey conducted within the course of the project revealed that current HEMS operators were seen as the most likely and trustworthy entity to find viable business models for UAM EMS. Second and third on the list were medical providers (hospitals and laboratories) followed by ground ambulance operators.

Business models will vary whether drones carry cargo or humans. The complexity will evolve when the flights will be in an urban environment. Cargo deliveries per drone have already been commercially used in the delivery of medicine by companies like Zipline, Matternet and Everdrone. The use of eVTOLs to transport persons is still waiting for the first type certifications before it becomes commercially possible.

The main reason eVTOLs are considered for future business case is linked to the expectations that, due to shorter warm up and cool down times compared to traditional helicopters, they could be dispatched quicker than helicopters especially for short-range missions, as well as for regular ferrying of specialists between hospitals. Other considerations are suggested below:

- eVTOLs are expected to produce fewer local emissions than traditional helicopters, although when compared to electrical wheeled vehicles the advantage is heavily dependent on the systems chosen and on local conditions. This topic should be studied at local level. For example, the grid intensity (CO_2 content in electric energy production) in Norway is very low. In such a country, transitioning from an internal combustion engine to an electrical one is more likely to make sense from an emissions perspective. However, in Germany, where coal and natural gas are still used for electricity production, the gains would be much smaller, if any.
- The faster dispatching of eVTOLs compared to traditional helicopters decreases time to target for shorter missions as well as creates the possibility of more frequent missions.
- eVTOLs generate much lower noise pollution compared to helicopter services. However, if the volume of flight operations increases with eVTOLs, the reduction in noise would be offset by increasing times, when noise is emitted.

Business cases should not be considered in a vacuum. It is important to also consider externalities and opportunity costs.

The document on UAM and business model is available for download here.

5: UAM integration toolbox

In a nutshell:

Acceptance is likely to play a significant part in the speed of development of UAM services. Cities should engage citizens to explore the benefits of UAM such as the ability to offer more direct routes between points without compromising on safety. Tools such as masterclass, surveys and maps support the decision-making process.

Transportation modes have so far been segregated between air, road, rail, and water transportation. The former needs a landing area, often surrounded by a control area for the aircraft to take-off and land. The latter three require paths, tunnels, roads, canals, railways, and harbours.

Models exist to visualize ground transportation networks. Other models exist to visualize commercial air transportation networks. However, none of these models offer the possibility to cross-reference urban planning information with airspace use data. Yet this is needed to properly plan UAM deployment in a city or region.

Whilst airports and helipads are generally protected areas, the landing points for urban air mobility are expected to be located in the immediate vicinity of people and other infrastructure. Urban air mobility will initially operate mainly in a small part of the airspace, below 150 meters where air traffic may become dense as flight volumes grow. Even dense traffic can safely be routed by using digital traffic management (U-space) services. Making UAM grow requires integration with existing modes in a safe, secure, and efficient way. It is not enough to only consider matters of aviation when designing UAM services. Also, the interaction with ground infrastructure must be considered, which is a call for spatial planners in local governments and for national infrastructure managers to engage.

Light-weight drones are currently used in cities for infrastructure inspections, mapping, photography or for law enforcement purposes. However, few European cities today see commercial helicopter operations at low altitudes and the amount of emergency air operations is limited.

City and traffic planners and their consultants who are used to work in two dimensions are expected to struggle to absorb and leverage the possibilities and challenges posed by a four-dimensional beast[3] that is aviation. Aviation adds complexity by shifting traffic in time, horizontally or vertically.

3 Time is the fourth dimension: airspace restrictions may change often.

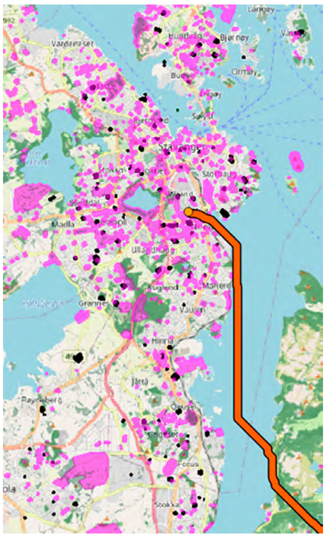
In addition, the ecosystem around air mobility, system providers, service providers, hardware manufacturers, digital or physical infrastructure is complex to apprehend and with interests that are neither fully defined nor always aligned. Moreover, the investments have been made in air mobility suppliers, are starting to seek return on investment by pushing manufacturers to put pressure on cities and commercial clients to acquire UAM services even without validation on their usefulness or viability.

Geospatial Information System

AiRMOUR developed a Geospatial Information System "GIS tool" to help visualise the four-dimensional urban space that UAM will operate in, and to better apprehend the possibilities and the risks of urban air mobility in a visual and intuitive way. The tool allows creation of geographical zones as volumes of airspace and attach specific characteristics to each for a designated type of operations by a special type of aircraft during a certain time. For example, schools can be no-overfly-geozones between 7am and 6pm on weekdays but allowed airspace in the evenings and on weekends. Also, hospitals may be no-fly-zones for leisure drones, but open for emergency cargo and air taxis.

Rather than setting the criteria in stone, the GIS tool is meant to let the stakeholders test alternatives and easily explore the impact. For example, a geozone area around a fuel station may quickly become a challenge if all fuel stations are protected with a buffer.

The tool is particularly well suited to engage with citizens, improve their knowledge and engagement and to help city decision makers make informed decisions. However, the GIS tools can also support flight planning purposes, by providing mission-relevant data. In this context, it will be important that cities and regions maintain and provide data related to UAM, for important consideration by UAM service operators. By providing open access to such data, cities and regions will create a de facto impact on the UAM industry irrespective if a legal ground for restricting flights exists or not.



Information used for the exemple routing:	Qualitatively evaluated layer weight
Kindergarden	2
Schools	2
Spare time activities	1
Trees	-3
Water	0
Landside	3

Figure 12: Example of a flight route around Stavanger.

Figure 12 shows how the AiRMOUR partner in the University of Applied Sciences Kempten worked on using a GIS tool to set up automatic routing, based on the listed criteria.

The software and document “GIS tool” are available for download here.

AiRMOUR’s training materials for UAM stakeholders

Citizens, city personals and other UAM stakeholders can take part in on- or offline courses such as the ones developed by AiRMOUR. Supported by expert interviews and research, our e-courses offer a variety of materials and speakers.

Should cities wish to develop their own courses, our trainers have shared the following insights related to the creation of successful e-courses. The most useful insights are:

- Each e-course should not have too many modules (it is about quality, not quantity). 3–5 modules are considered as optimum.
- Each module should not be too long and should include more than one speaker to keep participants engaged.
- Offering live webinars as part of the course, such as a live introduction and/or Q&A session is seen as beneficial to engage more participants.
- Speakers should be carefully selected based on their ability to engage, their knowledge and their following (i.e., are they well known in the industry).
- A mix of materials, such as recorded modules, downloadable files, short videos, and quizzes have proved to be successful.
- Having a downloadable certificate of completion helps to motivate participants to complete the course. If the certificate is accredited or endorsed, then this also helps raise the profile and credibility of the training.

The traction that the training curricula or e-course generates is expected to be a factor of the dissemination efforts, outreach, word of mouth, actual alignment between the advertised content and the actual content, and the willingness of the stakeholders to spend time on the topic. Consequently, cities may want to leverage the existing courses, such as the ones developed during the project and combine them with custom material.

The AiRMOUR project designed and delivered courses on the following topics:

- Introducing UAM & its potential to support Emergency Medical Services,
- Developing UAM-Emergency Medical Services
- Facilitating Urban Air Mobility for Emergency Medical Services in European cities.

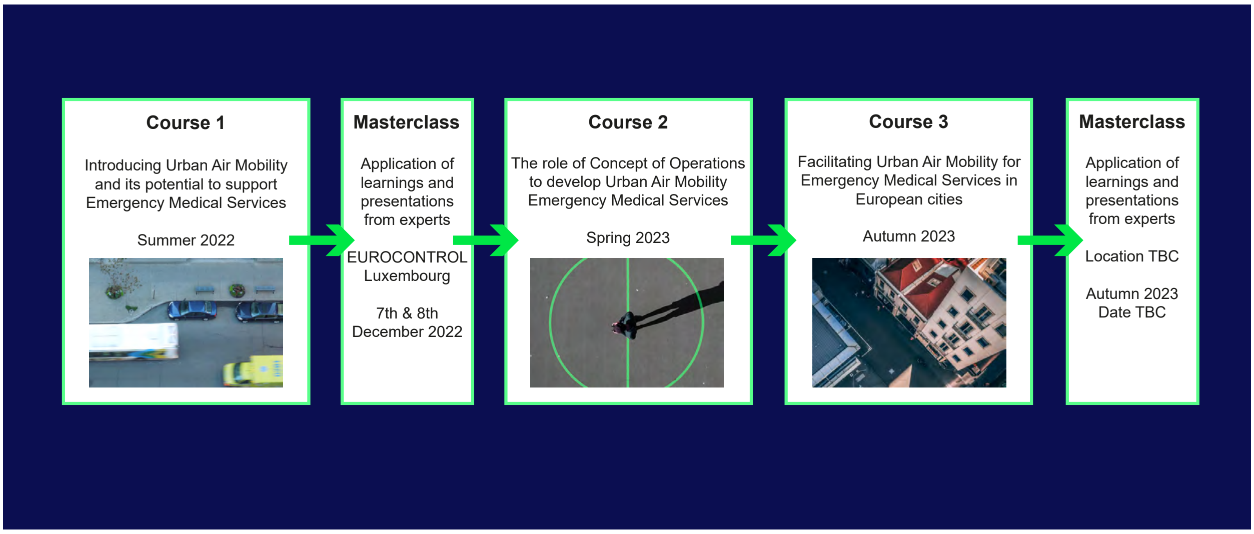


Figure 13: Overview of the training programme produced by AiRMOUR.

The AiRMOUR masterclasses are available on the AiRMOUR learning platform here.

6: Validating assumptions

Live demonstrations and simulations provide insightful results throughout the decision-making process. While the decision follows a process, each step of the process may be mapped and investigated as an opportunity for improvement. As much as possible, decision makers should seek to find and act on the root cause of issues rather than treating symptoms.

Mapping the processes

Beyond the challenges specific to the UAM flights, the new capabilities leveraged by advanced mobility have also a significant impact on the processes adjacent to the mobility. The transport of blood samples by drone is often looked at through the lens of economic benefits but the impact on the workflows at both source and destination needs to be investigated and understood. The report of this investigation is usually aggregated into a “CONcept of OPerationS” also referred to as CONOPS.

In hardly any case is it of the responsibility of the cities to prepare the CONOPS document. In most cases, the drone operators will be producing it although close interaction with the cities and clarification of operational requirements from the cities are likely to be integrated. Cities may also be at the forefront to address citizen concerns once the service starts.

Although the roles and responsibilities might change, the following breakdown should reflect an expected breakdown of roles and responsibilities between cities (or regions), authorities and drone operators.

Expected role of cities:

- Engage citizens to explain the real value-added use cases.
- Build know-how to understand trade-offs in choices (see below)
- Participate in the discussion on local rules for UAM operations in the sky. Corridors will limit the area subject to potential noise or visual nuisance yet aggregate the challenges over a determined potion of land. Corridors may or may not limit the growth of UAM in a city. Zoning (only communicating flight restrictions when necessary) will allow for higher freedom of routes yet be more complicated to roll out in a staged process. A combination may be needed to cater for the different types of flights and UAM vehicles foreseen in a city.
- Provide open data which you want UAM operators to consider in operations.
- Aggregate needs for vertiports, nature preservation, noise abatement, etc.
- Moderate completion of business models with the possible users of the service.

Expected role of UAM operators

- Demonstrate ability to fly and fulfil the needs of the mission.
- Demonstrate ability to provide an end-to-end service and integrate with existing workflows.
- Obtain approval for flights, vehicle, and organisation from competent authorities.
- Receive confirmation or formalize relationship with telecom providers for required level of connectivity service.

Expected role of aviation authorities

- Provide and implement regulations, standards and means of compliance.
- Provide up-to-date, machine-readable information on the airspace.
- Grant operational authorizations / flight permits
- Evaluate and approve flight areas, if applicable
- Validate conditions of transport of medical supplies (consult medical authorities if needed)

The issuance of flight permits in urban environments is within the rights of aviation authorities. Depending on the country cities may or may not have a say in the flight permit processes. The European Commission expects cities and regions to have a growing say in matters of UAM.

The document "Concept of operations of the selected UAM EMS scenarios" is available for download here.

Simulation tools to validate hypotheses

Adopting UAM will require new skills, process/workflow changes, and new equipment. Simulation is a great tool to investigate and understand the changes involved, yet it is only as good as the set of hypotheses and assumptions that are being made. Many of the technical components needed to simulate parts of a realistic UAM service exists as commercial or open-source software, for example simulation of the flight parts. However, a complete UAM simulation package does not yet exist.

By combining geospatial information, city 3D models, airspace information, and vehicle flight dynamic models into a flight simulator environment, the whole aviation part of the UAM scenario can be simulated in a realistic environment. Popular off-the-shelf flight simulators can simulate air traffic control and other airspace users through AI-based algorithms, connect to other simulations through online networking, or use a combination of these.

The outcome of the simulation will only be relevant to the part that is being simulated, and the quality of the information provided for the simulation will significantly impact the trustworthiness of the results.

As with surveys, simulations are also sensitive to built-in biases, hypotheses, and assumptions. For example, it is likely, because of noise, air, and ground risks among others that drones will seldom be able to fly a mission in a straight line. Does the simulation assume a straight-line distance, or does it consider likely limiting factors? Similarly, does the simulation consider acceleration and deceleration or has it been simplified to assume that a drone always flies at cruise speed? How much longer does a landing take when it is windy compared to calm? How long does the drone spend taking off until the cruise altitude is reached? Does the simulation include manufacturer data? Is the performance data based on ideal values or real-life, empirical evidence? How are atmospheric conditions reflected in noise simulations? Are local weather conditions considered? Such questions must be clarified before results of simulations are analysed.

Flight Simulation

As UAM aircraft become more popular, it can be expected that more proprietary simulators will become available and possibly included in the mainstream flight simulators. Several simulators exist for delivery drones. For example, DJI drones have a simulator for training of inspection by photography and mapping, and Parrot offers a simulation environment for research on autonomy, guidance, and control. However, cities should be aware that, if the vehicles are in their early development stages, the values extrapolated from the simulation that are shared likely represent an overly optimistic version of data that remains to be validated in real life.

Results from noise simulations may be overly simplified. Noise patterns are in reality affected by several factors both UAM specific (aerodynamic shape, payload etc.) and external (wind, humidity etc.), which only advanced simulators consider.

UAM simulation

Depending on how long it takes for a flight authorisation (flight plan) to be approved and how long the flight route is, the economics of UAM varies greatly. Jungwoo Cho et al, of the Korean advanced Institute of Science and technology proposed in their study[8] a topological analysis framework to identify *free* versus *usable* air space in a 3D urban environment. To incorporate the underlying geospatial complexity as well as vehicle's operational requirements, the authors imagined two geofencing paradigms – *"keep-out"* and *"keep-in"*. The "keep-out" geofence defines a boundary around static objects to keep UAV out. Those are typically "no-fly zones" where traffic is prohibited, the rest of the airspace being opened. The consortium has explored how no-fly-zones may be different for different type of traffic. Flights that have a higher societal value as will be defined locally or that are quieter or offer a lower visual disruption may be allowed in more areas, possibly at lower altitudes or during more hours than flights that would not meet local criteria. The "keep-in" geofence (geocage) is a 3D sphere to keep a vehicle in assigned volumes of airspace, for example inside assigned corridors.

While the keep-out paradigm mainly focuses on flight and public safety as well as security concerns, the keep-in paradigm mainly concerns social acceptance and traffic management.

The simulation of UAM operations also allows to estimate or confirm possible delivery time savings that drones offer compared to other modes of mobility. However, the data from simulations and projections can deviate significantly from reality in the case of both over-simplified or skewed assumptions or of missing validation and calibration steps.

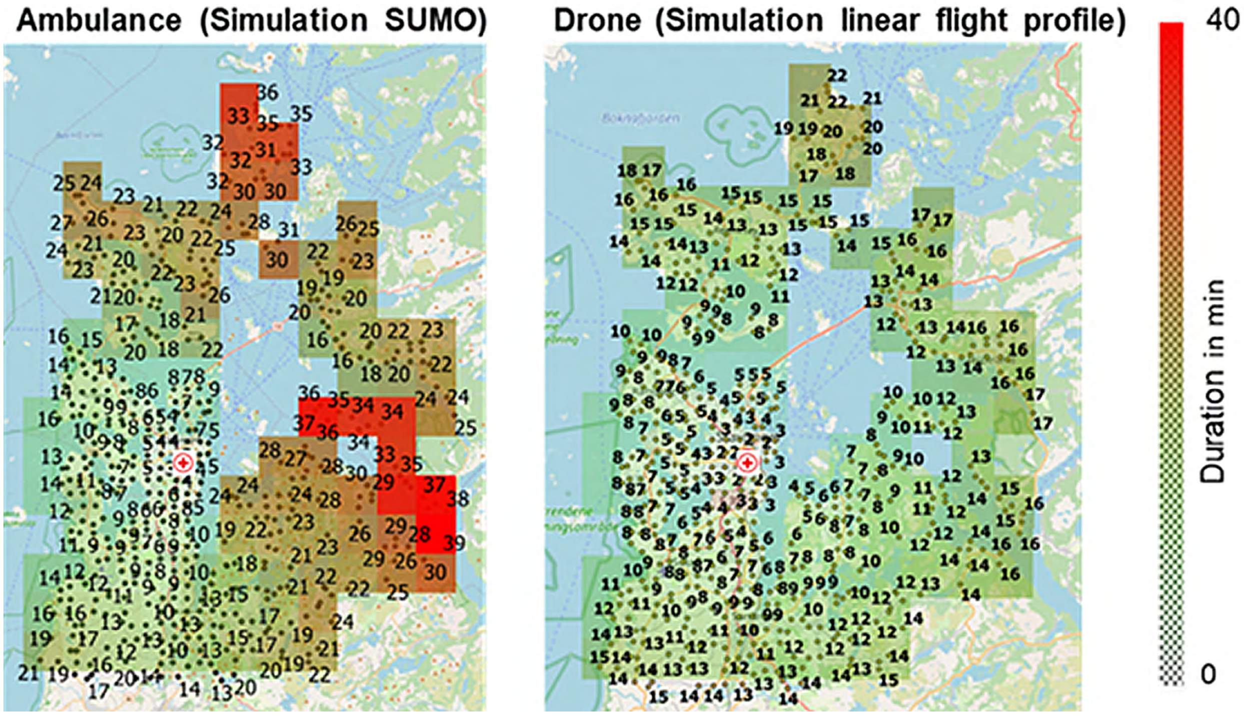


Figure 14: Simulation of travel time ground vs. air in the region of Stavanger.

Crowd simulations

Distinct types of crowds should be considered from different perspectives in relation to UAV missions in an urban area:

- A **cohesive/spectator crowd** is a crowd watching the activities of an event or at the scene of an accident. Its primary character is the fact that people are interested in watching something specific that they came to see (Berlonghi 1995[9]),
- An **escaping/trampling crowd** is involved in an evacuation procedure, attempting to escape from danger either of an actual or imagined threat to life,
- A **dense/suffocating crowd**, where movements of individuals are rapidly becoming more difficult or even impossible due to the density,
- A **violent** crowd that is attacking, terrorizing, and rioting with complete disregard for laws and the rights of others or an **aggressive/hostile crowd** that is growing verbally aggressive, disregarding the instructions of security personnel are likely to result in physical injuries that require medical attention.
- An **ambulatory crowd** (walking in and out of a venue, to and from parking areas or walking to use restroom or concession facilities) can form in various parts of urban space.

These types of crowds can be diverse, but typically (a) participants have a common purpose (e.g., gathering in proximity of shopping or recreational facilities such as parks, swimming pools, tourist attractions), (b) there is no prior organization, coordination, or leadership of the crowd and (c) the likelihood of aggressive/violent behaviours is low.

Data considerations

Data from cellular networks collected by the mobile operators is considered one of the most promising ways to understand human mobility. The advent of 5G networks and promising use case applications prompted mobile operators to collect and store Cellular Signalling Data (CSD) i.e., interactions between cell phones and cellular towers (such as attaching, detaching, paging) on top of traditionally collected Call Detail Records (CDR - recorded events that are triggered when a user receives or makes a call, accesses Internet or sends/receives SMS). The advantages of CSD data over more traditionally collected questionnaire data include:

- high coverage due to high degree of cell phone penetration,
- spatiotemporal character,
- high frequency of updating,
- low collection cost.

From the perspective of using human mobility data to inform drone route planning, the shortcomings of CSD include:

- lack of information about socio-demographic characteristics of phone users,
- lack of information about the level of exposure to eventual threats to phone users,
- poor spatial resolution,
- discontinuity in spatiotemporal data,
- relatively high cost of purchase (paid service).

AiRMOUR crowd simulations methodology: crowd density data collection

The AiRMOUR projects offers a methodological approach to collect qualitative data that can be used alongside other data sources to create a fuller picture of where in the urban space and when we can expect exposed individuals to be. Data collected during the workshop on the density of individuals represents reasonable assumptions about crowd presence and can be used in simulation tools that support UAV route planning.

More details on crowd simulation and possible workshops are available for download here.

Simulation of suitable landing sites

The partners in Kempten looked into the analysis of take-off and landing areas that would allow a passenger-carrying drone to land. The requirements as they are imagined for the Ehang E216 air taxi include maintaining a safe distance from nearby buildings, other flight obstacles and the ground. An example analysis in urban environment in a German City has been done depending on the flatness (Slope < 5°), roughness value (Topographic roughness Index < 5 cm) and compliance with the safety zone (radius 15 meters).

The results for the city of Dusseldorf (Germany) are shown in Figure 15 where potential landing sites are marked as green. This Analysis was only based on elevation data. Other exclusion criteria, such as roads, must also be considered according to the type of use case. Apart from landing sites on public roads, the majority are located on green areas.

This analysis shows that basic potential landing sites exist in urban areas. Additional validation must be completed to consider intermodality, compliance with the manufacturer requirements, connection to air/ground risk, charging infrastructure etc.

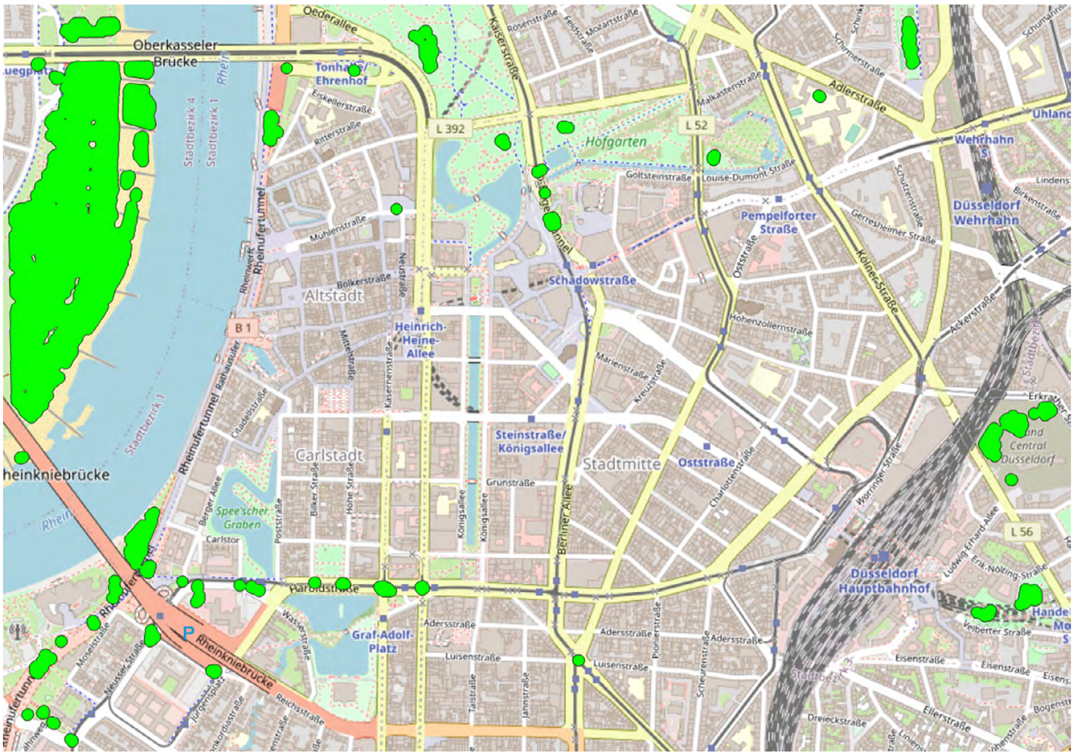


Figure 15: Determination of Take-off and Landing areas in urban areas.

In rural areas, the availability of especially ad hoc landing zones depends on the state of crops in the fields with clear seasonal validation. Evaluation of daily satellite imagery is helpful in this regard.

Finally, nature aspects, bird migration corridors, etc. need to be modelled.

7: Discussion

The UAM topic is so wide it can hardly be captured into one project. It needs to be broken down into small pieces in order to be "digested" and understood. Many of the pieces are complex, solved only in the long-term, open to subjective interpretation, dependent on other pieces, missing a link with real-life, or even completely missing. In addition, all stakeholders look at it with their own, coloured, glasses on – focusing on certain pieces of the puzzles, disregarding some others. Also, the AiRMOUR consortium faced limitations, barriers and challenges from the start. The project aimed to cover many elements from safety to cybersecurity, from social aspects to policy making, from environmental impact to legal assessments and from business sustainability to providing education.

We learned a lot. Yet at the end of the three-year project, it feels as if we were only able to scratch the surface of the topic UAM. Some topics, e.g., UAS traffic management (U-space) is largely left out as is the cross-border aspects of UAM. Municipalities are keenly aware that much of all traffic, including future drone operations, does not stop at municipal and that cooperation between neighbouring cities is important. Municipalities would like to know what aspects of UAM they could and should work on together with neighbouring municipalities. The same goes – but to a lesser extent – for medical organisations. A centralised lab may serve several cities, rather than just one. An overloaded maternity ward may send women in labour to a neighbouring town's ward. Such aspects are not addressed in AiRMOUR and would benefit from further research or documentation.

That said, for many of the stakeholders in this project – notably local authorities and medical service providers – AiRMOUR was (one of) the first time(s) they came into contact with the wider UAM topic and all aspects surrounding it. The realisation of the complexity of this topic has proven to be a catalyst for a change in attitude: from "this does not concern us" to "we need to learn about this" (municipality) and "this may be beneficial to us" (medical sector). Notably in the last year of the project, attention for and interest of AiRMOUR and the UAM topic in general has clearly risen. This can be – at least in part – contributed to AiRMOUR validation flights, training curriculum, increased in-person meetings with local stakeholders and the engagement of local "Champions" (someone within the city/region/lab/hospital at "high enough level", advocating the UAM topic).

Stakeholders like municipalities and medical sector actors have many questions that cannot be answered yet. Despite all its achievements, AiRMOUR has shown that for example business models, the environmental impact, the impact on (other/ground) traffic, visual pollution consequences, a large part of the legal framework or the (cyber) security threats can either not be measured properly or are still under development. Even the exact role of a municipality is open to interpretation, although not as widely at the end of AiRMOUR as it was at the beginning of the project.

During the project, participation in and appreciation of the trainings (including the in-person trainings) exceeded our expectations. Real-life lessons and experiences from regulators, industry players, medical actors or front-runner municipalities (turned into "bite-size" modules and courses) were experienced by participants as highly valuable and appreciated. Many medical and municipal stakeholders are currently looking at “what others in Europe are doing”. Where are the best practices? From whom can we learn? AiRMOUR contributed by making this kind of information more visible and more easily accessible.

It is much claimed that roll out of UAM stands or falls with the level of public acceptance or social embracement. Although this is likely true, one can also claim that roll out of UAM “stands or falls with the best possible safety levels” or “with viable business cases” or “with suitable regulation”. There are many factors that can make or break the rise or fall of UAM. As for public acceptance, exactly what these levels should then be is hard to determine, mainly due to a lack of real-life experience. Asking people (before and) after a demo flight / pilot case, does not properly represent the variety of drones that might fly in a city at some point (winch down cargo vs land; larger vs smaller cargo drones; lower vs higher flight heights; seeing multiple drones at the same time, etc). All this makes collected data hard to evaluate or compare between cities and between use cases.

UAM is not a one-size-fits-all -phenomenon. UAM should also not be seen as one-to-one replacement for current transportation modes. Correctly applied, UAM can reduce more polluting transportation modes whilst over time lowering cost and increasing service levels. We do expect to see an S-growth curve development of UAM services once regulatory and technical challenges are overcome. The size of the growth curve will very much be affected by the availability of raw materials and energy in a growing battle for means to fight climate change.

The AiRMOUR consortium hopes that these documents and the project outputs have provided readers with valuable insights. We highly encourage readers to continue discussions and knowledge building within their own organisations.

References

1 The Carbon neutral Helsinki 2035 Action Plan, 2018

2 The topic of mobility as a need is discussed in AiRMOUR's deliverable 2.1, Foresight Analysis.

3 Immobility as resilience, A. Ferreira et al, 2016

4 Description and engagement of stakeholders are described in the next chapter.

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AiRMOUR

This Guidebook for Urban Air Mobility Integration (AiRMOUR project deliverable 6.4) offers valuable UAM insights and provides an overview and understanding of necessary near-future actions – not only by urban communities, but also by operators, regulators, academia and businesses.

AiRMOUR, 01/2021 – 12/2023, is a research and innovation project supporting sustainable air mobility via emergency medical services. The EU-funded project has been focusing on the research and validation of novel concepts and solutions to make urban air mobility safe, secure, quiet and green, yet also more accessible, affordable and publicly accepted.

The multi-disciplinary AiRMOUR consortium consists of partners from Finland, Germany, Luxembourg, the Netherlands, Norway and Sweden. The consortium partners – including research institutes, aviation authorities, UAM operators and Emergency Medical Service organisations – are: VTT Technical Research Centre of Finland, City of Stavanger, EHang Scandinavia, Forum Virium Helsinki, Hochschule Kempten, Linköping University, LuxMobility, NORCE Norwegian Research Centre, Regionalmanagement Nordhessen GmbH, Robots Expert Oy, Swedish Civil Aviation Administration Luftfartsverket, Swedish Transport Administration Trafikverket and University Medical Center Groningen.

Read all project deliverables: **airmour.eu**.

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