UAM system integration – system analysis and noise simulations in support of regional and city planning

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Abstract

This study aims to raise awareness, develop knowledge, and provide recommendations that will support stakeholders in the development and implementation of drones in urban environments. There is an ongoing and complex transition towards integrating UAM (Urban Air Mobility) systems into urban environments. This will impact two main existing environments: the air transportation system and cities and regions. Since drone operations affect the current aviation and ATM (Air Traffic Management), a truly complex infrastructural system, drones cannot be developed independently. It remains a challenge for developers to demonstrate concepts on a small scale, and large-scale trials to study the effects of UAM have yet to be conducted. Cities and regions need to prepare and plan for the implementation of UAM in parallel with this development. The study has collected data on the context of Stockholm city and region. The recommendations are to adapt a "rich picture" and system description including relevant actors' roles and responsibilities and identify in detail development and planning processes. Two ConOps for drone concepts and UAM are analysed with respect to noise and innovation. This provides a good overview for handling expected complexity when integrating drones in Stockholm. The rationale holds that a thorough problem formulation of this complex transition will increase the chance for success.

1 Introduction

There is an ongoing and complex transition towards integrating UAM (Urban Air Mobility) systems into urban environments. This will impact two main existing environments: the air transportation system and cities and regions. Since drone operations affect the current aviation and ATM (Air Traffic Management), a truly complex infrastructural system, drones cannot be developed independently. It remains a challenge for developers to demonstrate concepts on a small scale, and large-scale trials to study the effects of UAM have yet to be conducted. Most research and reports on drones relate to regulations from authorities, development of vehicles, airspace design, autonomous systems infrastructure, etc. When these technical and legal issues are resolved, a new phase of implementation and full integration into cities and regions will commence. UAM is new, and there is great uncertainty about what UAM will entail and what effects, benefits, and consequences it may have. Cities and regions need to prepare and plan for the implementation of UAM in parallel with this development. The system of interest in this study is the urban environment that UAM will be integrated with and that will manage the implementation of UAM. The study has collected data on the context of Stockholm city and region.

Experiences from earlier research projects give an indication of anticipated challenges with respect to cities and regions. Goal-driven planning processes do not give much room for innovation in public transport. This is a lesson learned from a case of introducing waterways and boats into public transport in Stockholm [1]. There is a built-in resistance due to properties commonly assigned to mature and reliable infrastructure systems [2]. Small-scale novel

systems do not come out well in assessments with methods, tools and processes driven by goals that are tailored for high-capacity transportation systems like road and rail. In another case, aviation noise issues were studied. It was found that aviation noise causes annoyance and health effects in ways that are caused by both acoustic and non-acoustic factors [3][4]. Annoyance may lead to community complaints [5][6] and conflicts with NIMBY (not-in-my-backyard) effects. Goal conflicts and dilemmas with underlying wicked issues in aviation were identified [7]. These issues are known to be very difficult to manage, however, there are methods that may be applied to manage wicked and societal issues [8][9]. Finally, the field of noise and acoustics is a very hard subject to grasp, which may add to misunderstandings and reinforce non-acoustic annoyance. Noise simulations and visualizations of noise footprints on the ground are valuable tools when communicating wicked and social issues as well as to explain acoustics, and noise measurement [3][10]. This is an example of how simulations may be used to reduce annoyance. It is essential to proactively avoid conflicts during implementation of changes in someone's "backyard" since they may have implications on development and innovation for aviation actors and may restrict their operations.
There are analogies to this with UAM. It is a new mode of transportation being integrated into the city. Drones generate noise in similar ways to aviation noise. It is therefore anticipated that UAM will meet similar built-in resistance when integrated into existing urban transportation systems. In addition, when drone services, in small scale or full-scale UAM, are implemented they may meet resistance from citizens if drones are perceived annoying because of their noise (or other undesired and unintended consequences). In a worse case, this will lead to community complaints, delay of permits, restrictions, and rather foster a drone resistance rather than a drone acceptance. Like aviation noise issues the way UAM is implemented may have direct effects on citizens and integration and indirect effects on its success. There are strong interests in successful implementation of drone systems and a fossil-free new transport economy and business:

*"We believe that if our strategy is implemented **properly**, the drone market could be worth 14.5 billion euros ($15 billion) by 2030. It could also create 145,000 new jobs in the European Union"*

-Transport Commissioner Adina Valean [11].

In the interest of drone technology development and air transportation innovation this project aims to increase the chances for maximizing benefits for societal and human needs and minimize undesired and unintended consequences. Many concepts and services that drones provide can save lives, and these potential benefits, among others, should not suffer from a failed UAM system integration. With emphasis on this early phase of concept development a system analysis can guide development of a UAM concept of operations (ConOps) [12] and identify potential blockers with relevance and leverage of a ***proper*** implementation of UAM. A successful problem formulation offers several viewpoints on a problem's nature and a strong debate in different ways to look at it like a "rich picture" [13]. The rationale is that a thorough problem formulation of this complex transition will increase our chances for success.

Purpose and delimitations

The purpose of this study is to analyze UAM from the perspectives of the citizens and the city and identify potential blockers with respect to noise and innovation.

1. What does Stockholm city need to implement UAM properly?
   - What unknowns and unanswered questions are there for a UAM concept of operations?
   - What support can noise simulations give in implementation strategy for UAM?

Studying implementation of UAM is delimited to a study of an envisioned system. The scope of this study does not consider the unresolved technical and regulatory issues with respect to the flying system. An assumption is that the city needs to prepare for a fully developed UAM system. The study has chosen to have the citizens of Stockholm focus and the city side of UAM implementation. Although there are other aspects of concern in relation to drone acceptance, like safety and integrity, this study is limited to noise issues.

2 Method

It is anticipated that the challenge to manage the complexity of implementing UAM includes messy and wicked problems [9]. When strategic decisions are rare and complex then problem framing, and problem formulation has been shown to be at least as important as traditional problem solving in engineering since there is no optimal solution to "messy or wicked problems" [14]. A successful problem formulation that gives a "rich picture" [13]. allows externalities to be factored in already in design to avoid surprises with undesired and unintended consequences. From a systems and engineering perspective, it is best practice to perform a system analysis and frame problems sufficiently to assure understanding of what choices have been made, what was selected, prioritized and why. All design requires the ability to deal with trade-offs and compromises. Special emphasis in this analysis has been placed on applying a working method when one is not sure in advance which boundaries are relevant and which scope of analysis should be prioritized, given what one aims to influence. To formulate the problem and understand differences in the system depending on whether one starts from a solution and defines the system that is part of this solution or instead considers the problems or externalities this solution has and what features of the system that is associated with them.

Interviews, workshops, and documents

The project is conducted with a broad approach that continuously engages stakeholders through discussions and interviews including the Swedish Transport Administration and Agency, the City of Stockholm and its Region, the Swedish Environmental Protection Agency, air traffic service providers, drone manufacturers' networks, and more.

Interviews have been complemented with studying webpages and public reports published by Stockholm region, Stockholm city, governmental agencies, authorities, and administrations. Consolidation of this material describes planning processes, organisational dependencies and goals that drives these organisations.

Concept of Operations – ConOps

A system's concept of operations (ConOps) is developed through steps that describe the envisioned system, identify the various classes of users, identify the different modes of operation, clarify vague and conflicting needs among users, prioritize the desired and optional needs of the users, support the decision-making process that determines if and how a system should be developed. A ConOps is a common part of the early concept development stage phases[17].

- Needs Analysis Phase. The need for a new system. It addresses the questions "Is there a valid need for a new system?" and "Is there a practical approach to satisfying such a need?"
- Concept Exploration Phase answering the questions "What performance is required of the new system to meet the need?" "Is there at least one feasible approach to achieving performance at an affordable cost?"
- Concept Definition Phase. The concept definition phase selects the preferred concept. It answers the question "What are the key characteristics of a system concept that would achieve the most beneficial balance between capability, operational life, and cost?"

Several alternative concepts must be considered, and their relative performance, operational utility, development risk, and cost must be compared. Given a satisfactory answer to this question, a decision to commit major resources to the development of the new system can be made. A general ConOps has the following characteristics (after) [12]:

1. Description of the current system or situation, including scope and objectives of the current system, operational policies and constraints, modes of operation, classes of users, and the support environment for the current system. Describe the reasons that motivate development of a new or envisioned system.
2. Nature of proposed changes and/or new features, including the justification for those.
3. Operational concepts for the proposed system, including scope and objectives for the proposed system, operational policies and constraints, modes of operation, classes of users, and the support environment.
4. Operational scenarios describing how the proposed system is to perform in its environment, relating system capabilities and functions to modes of operation, classes of users, and interactions with external systems.
5. Operational and organizational impacts on the users, buyers, developers, and the support and maintenance agencies, during development of the system and after installation of the system.
6. Alternative and trade-offs considered but not included in the new or modified system, analysis of benefits, limitations, advantages, and disadvantages of the new or modified system.

Some adoptions are made with respect to the sociotechnical characteristics of the system of interest. For example, the cost is not for the developers to build, but consequences and environmental cost if implementing the system.

System analysis – problem formulation

In a common ConOps it is common to have a product development perspective. In engineering systems, rather a re-visioning [15] of systems have been suggested to capture problem areas from other perspectives than one's own view. System (re)thinking entails twisting and turning the system and adopting different perspectives. A model supporting this rationale describes solution space, design space and problem space (Figure 1). At any point in analysis the perspective may alternate between these and will vary and contribute to a "richer picture" from which aspects of most relevance and leverage can be chosen depending on the scope of analysis. Solution space includes the system or concept in question, a solution to a particular need or problem. The surrounding design space includes alternative designs, potentially future designs or those abandoned in trade-off analysis. Solutions and alternative designs cause problems which are represented in nodes in the problem space. A re-visioning of UAM has been performed from three main stakeholder perspectives. 1. Citizens, 2. Stockholm city and region, and 3. Drone developers and operators. For each perspective a network of problems may be identified associated to UAM and their interests and goals. For the scope of this study only perspective 1) Citizens and 2) City and region is problematized in this paper. The reason is that most research and reports reviewed during the project had perspective 3) Drone developers and operators, and there was less written on the first two. Problematization of Citizens perspective includes a brief on findings from other noise issues studies. Experiences from an earlier project on aviation noise issues were compared with UAM to identify analogies and anticipated issues with UAM noise in the city. Problematization of Stockholm city and region perspective includes a brief of what processes for city planning and strategies that are linked to noise and implementation. Experiences from an earlier project on integrating waterways into the public transport was compared with UAM integration to identify analogies and anticipated issues with innovation and transformation.

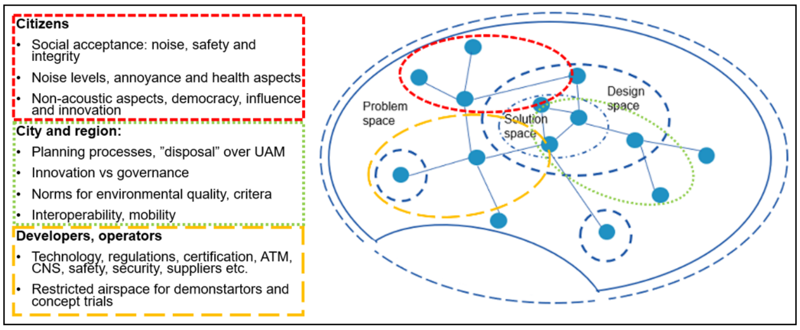

Figure 1: Network of problems associated with UAM from various perspectives.

3 Results

Results presented follow the process of ConOps (concept of operations) as far as possible with the information at hand of the envisioned system, its' benefits and drawbacks and impact, positive and negative, for aspects influencing implementation of UAM. An overall need comes from the current urban transportation system that suffers from congestion and capacity limitations in public transport. Urbanization is increasing and cities are expanding, which needs mobility to increase. Local environmental impact on citizens from noise and air pollution are severe. Global needs for reducing climate impact also puts great pressure on the city to reduce fossil-fuel transport.

National transport policy goals, including climate goals

The city's planning and development follows national goals, strategies, and plans which in turn are aligned with EU ambitions and based on UN's SDGs. The global goals derived from EU and UN SDGs and although for local environmental quality are emphasized, for example int the "Green deal" [18], climate seems to be prominent.

National political goals for climate and transport relates to both transportation of people and goods [19]. The overall goal of the transport policy is "to ensure a socially efficient and long-term sustainable transport supply for the citizens and businesses throughout the country". The functional goal state "the design, function and use of the transport system must contribute to providing everyone with basic accessibility with good quality and usability, as well as contribute to conditions for development throughout the country. The transport system must be equal, i.e. respond equally to women's and men's transport needs". Lastly there is a category of goals to ensure considerations of citizens and their living environment. The consideration goal states "the design, function and use of the transport system must be adapted so that no one is killed or seriously injured, contribute to the achievement of the overall generational goal for the environment and the environmental quality goals, and contribute to increased health".

The Swedish Transport Administration (TRV) is the Government agency responsible for the long-term planning of the transport system. All mode of transportations is included in an intermodal approach: “The transport system needs pedestrian and cycle paths, roads, railways, ports and airports that interact and complement one another to meet societal needs. An intermodal perspective is fundamental to planning how we should use our infrastructure in a smarter, more efficient manner”.[19]

The Swedish Government’s policy goals for transport and climate is that “by 2030, emissions from domestic transport (excluding aviation) shall be reduced by 70 percent compared to 2010, with zero net emissions by 2045. The vast majority of Sweden’s domestic carbon dioxide emissions from transport, approximately 93 percent (2017), come from road traffic. As road traffic constitutes around 85 percent of passenger transport work and 50 percent of freight transport work, the inescapable conclusion is that the main way to achieve climate goals is fossil-free transport” [19]. Electrification and digitalization are argued to contribute to reaching these goals, for example by distance working, smart travel, electrical vehicles, and autonomous cars. By working from home, the aim is to reduce the overall number of travels. Smart travel apply digital tools to select travel off-peak hours to mitigate capacity limits in public transport and on the roads. Replacing fossil fuel cars with electric cars will reduce fossil emissions. Autonomous cars are anticipated to reduce the number of private cars and reduce congestion.

The system of interest in the APIS-project is the urban environment that the UAM will be integrated with. The Stockholm region is one of Europe’s fastest growing metropolitan regions. “By 2050 it is expected to be home to 3.4 million inhabitants. This rapid population growth is positive for the region yet brings with it major challenges-challenges that demand good planning and effective cooperation between many different organisations and stakeholders” [20]. The four top challenges expressed by Stockholm region are:

1. Facilitate population growth while improving the region’s environment and the health of its inhabitants
2. Address capacity shortages while meeting growing needs
3. Become an internationally leading metropolitan region in a growing global competitive landscape
4. Reduce climate impact while enabling increased accessibility and economic growth

One goal is an accessible region with a *good quality of life* with sub-goals such as:

- At least 22,000 homes should be built each year.
- Travel times between regional cores and Arlanda Airport should be competitive with car travel times.
- The percentage of the county’s inhabitants who experience disturbances caused by traffic noise and poor air quality should not increase.
- At least 95 per cent of new settlements should be built in the region’s most accessible locations.

Sub-goal three address “consideration goals”. One significant environmental factor that affect health and quality of life negatively is noise. More and more people are disturbed by noise, above all from road traffic, trains and aviation, but also from neighbors and fans. The residents of Stockholm's inner city and those who live near Arlanda and Bromma airports consider themselves the most disturbed. A health effect of noise exposure is disturbed sleep and long-term exposure also increases the risk of heart and vascular diseases [21[[22][23]. “In total, it is estimated that 395,000 people, corresponding to 17.7 percent of the county's population, are exposed to noise levels from traffic (road, rail or air traffic) that exceed 55 dB LAeq, 24h. If one instead starts from the WHO guidelines, which are stricter than the Swedish guidelines and set solely from a health perspective, it is estimated that 926,000 people (corresponding to 41.6 percent) are exposed to at least one noise source at home” [23].

Even with strong need and emphasis on collaboration to set the direction for the region the municipals, at a city level, have local independence to develop strategies for how to reach the goals. Strategies for realizing this master plan is governed locally. There is also a great responsibility for the city to keep disposal over a potential UAM and govern this implementation properly to balance the various goals they are accountable for.

Envisioned UAM

These needs do not directly argue for the need of a UAM system. UAM has societal benefits and addresses needs linked to urban transportation and climate goals. However, to have real impact on carbon emissions, congestion and mobility depends on its scale. UAM probably needs to replace a significant number of fossil-fuel vehicles and replace ground vehicles as transportation mode to have real impact on climate impact and congestion. To be competitive and contribute to public transport capacity it probably needs to become a “large-scale established system that can bring down costs and offer competition to trains and become part of the public transport” [24]. Currently, there is a lack of a full-scale UAM concept for the city of Stockholm and the Stockholm region. There are a number of operational concepts that are relevant to study to envision a future UAM system. Each of the concepts has identified value for a specific actor or service. The general hope is that UAM can enable faster and potentially more reliable transport than corresponding ground-based alternatives. It is also hoped that UAM can contribute to increased mobility by supplementing existing transport systems with a more efficient alternative. In addition to improved transport services, UAM also has the potential for societal benefits in the form of faster response to emergency services and medical care, which in practice can save lives [25].

Despite the lack of a UAM concept for Stockholm there is plenty of evidence that this development is on-going and there are grand visions for UAM: "In 2045, fossil-free, fast, simple and cost-effective transport is a concrete reality. There is a nationwide fossil-free transport system for goods and people with electric and hydrogen-powered drones in the lower air. Taking drone taxis between different neighborhoods and cities is a reality" [26].

Industry investments are significant. “According to research firm Drone Industry Insights, the global drone market in the broadest sense is currently worth US$26.3 billion and growth is driven more by commercial drones than recreational drones. The drone industry is projected to reach $41.3 billion in revenue by 2026, which compares to the global helicopter market currently valued at $48.2 billion” (Doneii, 2021 cited in TSL, 2023). According to the EU's "Drone Strategy 2.0", it is expected that a large-scale drone market will have the potential to generate 14.5 billion euros and contribute 145,000 jobs in Europe by 2030 [27].

Proposed new features with UAM

The new functions the UAM offers is that it is a fossil-free (electrical) mode of transport that facilitates point-point travel by air and by this allows avoidance of congestion on the ground and saves travel time, which increases accessibility and mobility. The term drone is used for several types of aircrafts. Unmanned Aircraft System (UAS) is used to define unmanned aircraft, which also includes traditional aircraft without pilots on board. But UAS are also used for smaller craft that are flown by operators from the ground. The term drone is also used for aircrafts that can land vertically. This includes the VTOL family (vertical take-off and landing) and eVTOL, which are electric VTOLs. For UAM, the whole idea is to be able to take off and land on a small in an urban environment, so different types of eVTOL are what is meant by drones in this study.

The main and innovative function of UAM is bringing airborne transportation all the way into an urban environment using the ability to fly from point to point instead of flying from airport to airport. This provides new conditions for the urban environment and its mobility. Using drones to transport goods, you can avoid traffic queues and shorten the journey time compared to traditional ground transport. This requires a transformation of traditional air services to accommodate interoperability with drone services with improved or sustained safety and security.

Drone service concepts

Below are ongoing concepts described that APIS has encountered over the course of this analysis only in Stockholm and its surroundings up until 2024. Replacing medical ground transport deliveries between hospitals and clinics with airways, will reduce delivery time and reduce risk of delays traffic congestion. If replacing fossil-fuel vehicles this drone service will also contribute to reducing carbon emissions, which is not the case if ground deliveries are using electrical vehicles. Another example is to use drones to deliver defibrillators. The idea is simultaneously sending alarm for cardiac arrest to regular emergency services and to deliver a defibrillator with a drone, awaiting arrival of ambulance and health care personnel. Health care services have potential to save time which may save lives. With police and fire services this group of concept contribute to security and safety to all citizens. Another field for drone services is last-mile delivery of small packages. If replacing fossil-fuel vehicles it may reduce carbon emissions and ease up space on busy streets. An example is also to replace logistics with a nearly empty truck at the end of their delivery route. A drone hub can be used for last mile delivery and be the last stop for a truck but extending services with drones further out in a logistic network.

These concepts differ in scale and route structure. Some flights have a regular designated destination, like the case between hospitals, when destinations are known. Other flights’ destinations will depend on where the emergency or package delivery is and where there are public vertiports. These examples give an idea of the proposed system and that the UAM is a system encompassing several different concepts. It also describes the potential scope and objectives of the proposed UAM (Table 1).

Scale, scope and temporality of UAM integration

Historically we have seen artefacts such as the light bulb and telephone grow into energy systems and communications systems. Today these systems are often seamlessly intertwined. Add to these cars that together with road infrastructure grew into road transportation systems. Transportation systems contribute to noticeable externalities challenging cities today. Probably in a way that was never anticipated when cars and road systems were first introduced. The situation in ground transport has in many cities become unsustainable with carbon emissions, congestion, and cars everywhere in our cities. These are examples of undesired consequences of engineering systems [15] that we in some ways have lost control over. The demand for alternative ways of getting around has grown as a result of urbanization [28]. Combining systems for energy, communication and transportation gives rise to new opportunities, like UAM. With lessons learned from history it is possible to proactively anticipate how drone concepts are likely to grow in scale and evolve to full-scale UAM systems. For example, "in a network such as UAM is supposed to be, there are conditions to increase traffic significantly for each new node in the system"; "operating costs are expected to fall in line with volume growth due to economies of scale"; "this creates the conditions so that once UAM is established, traffic can increase substantially" [28]. This means that initially the traffic is relatively small but of relatively low complexity. This will be true for isolated concepts (Table 1) evolving one by one on a small scale. When combined and maturing then density and frequency increase to significantly higher complexity, into a full-scale UAM.

Noise issues from aviation and drones

In the regional plan (SKR, 2018) the problem with noise and emissions from road traffic are "estimated to be able to decrease somewhat in the medium and long term thanks to technological development, for example through increasing elements of electrification". The logic behind this statement is not further explained but may be questioned. Reducing the number of cars and reducing the speed limit could reduce noise emissions from road traffic, but electric cars are not silent. They are silent or almost silent below 30-40 km/h. Otherwise they sound like any other car, due to their weight and tire friction. This logic of electric vehicles being silent has been used in arguments for electric aviation too. But it is not primarily engines that make noise. For aviation, it is mainly approach and landing that is annoying, when airplanes fly at a lower altitude and fly over slower, which increase duration. It is the air resistance flaps, slats, and above all, the landing gear that make noise and help a plane to reduce speed and land. Noise will change with electric aircraft and drones, but not go away. Aviation noise is perceived to be more annoying than ground transport [21][29]. There are some differences that may make aviation noise more annoying than road traffic. For one thing cars are everywhere, all the time in an urban context. Sound perception is sensitive to reacting to sudden or rapidly approaching sounds. Airplane noise is intermittent, coming and going. A continuous sound is easier to ignore. Another psychoacoustic detail is that we experience sound more distracting when we cannot see what is making the noise. In the preliminary study regarding drone transport between Region Stockholm's emergency hospitals, the City of Stockholm emphasized noise considerations as one of the central aspects to consider when planning route and listed some similar aspects: Sound sensitivity varies between different people, which leads to different reactions, the wider the spectrum of a noise, the more people react to it, unusual noise can trigger a stress reaction and repeated sounds are more difficult to accept than single ones.

An example of noise management issues comes from Boston Logan airport [34] where precision flights were seen as means to increase capacity at the airport. However, this also increased the precision of noise. Precision flights gave rise to an increased number of noise complaints for those who now received more concentrated noise. Another example is when traffic was rearranged at Arlanda, which in effect reduced noise for 35,000 people but 5,000 new citizens were introduced to new and loud noise. This led to community complaints. One reason was the fact that they had chosen to live at "noise safe" distance to Arlanda and were not prepared that the conditions would change. Aircraft noise changes affect house prices and private values, in addition to changing the quality of life for those who feel disturbed by aircraft noise. In Boston, they experimented with "fair" noise distribution, but it was difficult for the reasons mentioned, that in numbers it would loke fair, but those introduced to aviation noise reacted strongly. There are also non-acoustic factors [3][4] that affect the degree of annoyance from aviation. At a very basic level it concerns individuals' experiences and feelings such as anger, control, fear, justice, trust, and satisfaction. These are governed

Table 1. Drone concepts and services, suggested size and route structure.

CONCEPT	SERVICES	SIZE	ROUTE STRUCTURE
Emergency response	Medical deliveries between hospitals	small	Network - fixed nodes
	Defibrillators	small	Star (hub and spoke) fixed facility but randomized destinations
	Police surveillance	small	Mobile facilities - surveillance - hovering
	Monitoring, forrest fires, power lines etc.	small	Planned surveillance area
	Mapping – forest, landscape, city planning, wild life, etc...	small	Planned surveillance area
Drones as scarecrows	Scaring geese away from public outdoor bath places	small	Local facility
	Scare birds and game away from runways, airports, or crops	small	Local facility
Last mile delivery packages	Smaller drones for "last-mile-delivery"	small	Star (hub and spoke) fixed facility but randomized nodes
	Food store case - outbound from truck end station/drone hub to smaller stores	small	Star (hub and spoke) fixed facility but randomized nodes
	Personal food delivery - from city center to recreational areas/archipelago	small	Star (hub and spoke) fixed facility but randomized nodes
	Fast food delivery - from central kitchen to pick-up stations/drive-through/home	small	Star (hub and spoke) fixed facility but randomized nodes
Passenger and goods	Larger drones - airport to airport	large	Regular fixed routes
	Larger drones - airport to location – shuttle	large	Star (hub and spoke) fixed facility and nodes
	Larger drones from place to place (inner city, suburb - taxi service	large	Network - fixed nodes
	Larger drones from home - private drone	large	Network - fixed nodes
	Spare parts deliveries - logistics system for companies	large	Regular fixed routes

by, among other things, perceived transparency, communication, predictability and respect from system builders and decision makers during planning processes. Good examples of how to reduce the degree of annoyance are local job offers, compensation, noise measures and forums with influence over planning. There is an increased emphasis on citizens' quality of life presented through the European green deal [18] which also puts emphasis on democratic processes. In summary, it is expected to become a challenge to come up with strategies that citizens agree on.

Managing noise from drones and UAM is critical for their acceptance in society. At this point, no one knows what the future noise exposure from UAM will be and less how annoying it will be perceived. This is partly due to the lack of explicit UAM concepts specifying drone traffic, including fleet composition and size, airspace design, dominating noise characteristics. There is still limited knowledge about the noise generated by drones, its' propagation, noise exposure and annoyance it will generate. However, even with noise control measures, one cannot regulate or design the air space such that noise exposure from drones is eliminated. Considering that drones are planned from point to point in an urban environment a new social group will be exposed to, and potentially annoyed by, drone noise. In UAM it might be possible to randomize noise even on regular routes to spread and share the noise among many, as a way to avoid reaching the annoyance threshold of a particular group or area. When facing a UAM in the city there will be more obvious alternative placements of vertiports than when presenting expansion or changes to neighbours to established airports. General scepticism using the concept of NIMBY should be expected. This is especially a risk if the citizens have not been invited for information, communication and even influence over this change, increasing to non-acoustic annoyance. This will have a negative effect on integration processes.

Innovation issues in public transport

In a Swedish Transport Administration's capacity investigation from 2012 it was already stated that the transport system and not least Stockholm traffic suffers from a lack of capacity. This leads to costly delays in traffic in our metropolitan areas. The need to change and develop solutions for these challenges is clear. However, the alternatives for renewal are limited as the land in and around central Stockholm is almost completely exploited. In a city with limited land area and a region partly built on islands, the number of railway and subway tracks in and out of Stockholm is few, which limits all rail-based public transport. Today's public transport system is well established, making it robust and reliable. However, a downside is that well-established and mature system tends to stagnate in development: it continues to expand, but no new functionality is added. It was mentioned in the capacity investigation that the waterways have a potential as relief and complement to the established public transport system.

Findings in the study identified that these challenges are general and have been studied in technology management and industrial dynamics. Large technical systems (LTS) is a research area that explains how large complex systems emerge, are established and function [2][30]. These systems can be described as seamless networks of political, technological, economic and social subsystems [2]. Things that affect innovation and implementation, not least the introduction of a new mode of transport and transport system, are, for example, established regulations, planning processes, models, tools, socio-economic calculations called a "regime".

The report also identified several advantages of waterborne public transport, for example that the traffic does not claim any street space of its own but is space efficient, that the waterway is already laid (if you define the water that can be occupied by traffic as infrastructure) and that waterways can create shortcuts in the city and between the outer parts of the region and thus generate shorter journeys. With efficient waterborne public transport, it would be possible to build more lakeside and attractive locations by offering good accessibility via the water. In addition, the waterways can relieve the land-based infrastructure and act as redundancy, for example, when bridges are lost.

The study found a need to strengthen the connection between urban development, housing construction and traffic planning. At present, however, waterborne traffic is rarely included as a real alternative in strategic planning. The small traffic volumes of the existing waterborne public transport, in comparison with other types of traffic, make it difficult to make a fair assessment. New modes of transportation may even require special treatment since they will lack planning documents and have low quality input data in current planning processes.

A system is greater than the sum of its parts which means that adding drone concept under development in is not necessarily resulting in a UAM system. In a thesis [31] the work of the City of Stockholm within a Strategic Innovation Platform was studied. It was found that here is a challenge in either implementing a strategy "top-down" or building a solution "bottom-up". In the case of UAM, a variety of concepts but should have have an overall strategy for a whole. Emergent combinatory effects of initiatives, each for a good reason, does not guarantee a systemic positive result. On the other hand, an overall strategy can be uncertain, and you will still not have all the answers before testing and this is advocated by those who want to work with demonstrators and isolated concept development.

The concept of "experimental governance" was studied [31]. It deals with receiver competence from local experiments and demonstrators. Here, difficulties were identified with management organization and experiments, where the projects were temporary organizations while the recipient organization has standardized formal processes and methods, as well as strict goal management for higher level goals and plans for nations or regions.

There are many different areas, departments, committees, administrations. In the city of Stockholm alone, more than 50,000 people work in around 50 different departments and companies covering schools, elderly care, social services, planning, housing, mobility and infrastructure [31]. In addition to this, many strategies are based on cooperation with different authorities that have different focuses and related laws and regulations.

Stockholmers' focus

The European Green Deal includes a criterion that no people or places should be left out [18]. In this project, it includes the residents who will be affected by the implementation of UAM in their immediate neighbourhood with regard to noise and annoyance. Residents influence their local environment through political influence, which provides a mandate for the city's developers and system builders. Stockholm city want to increase influence beyond political elections every four years in accordance with the government's democracy strategy (Government 2018, p. 39). In the city of Stockholm's quality work and innovation, citizen of Stockholm is emphasized: "The city should not only have citizens of Stockholm in focus, we shall have their focus. Something that requires us to be responsive and to have an active dialogue with the target groups" [32]. The functionality expected by Stockholm city is to assure attractive conditions for residents and businesses and sustainable development [19]. Involving residents is complex. "In complex social and wicked problems there exist multiple "perceived realities" since humans make different assumptions about the world and their situation, and simply have different worldviews. "Wicked problems is due to this, guaranteed to include several different opinions about the problem, both within, between and outside of organisations in systems of systems with multiple stakeholders, actors and groups." [16]. In several of the processes and strategies produced by both the city of Stockholm and Region Stockholm, the importance of including users, residents and travellers in the development of the common environment is mentioned. "The city needs to involve target groups and other actors systematically in the quality work, make it easier for Stockholmers and businesses in the meeting with the city, ensure equality in the city's service and services, develop the work with opinions and complaints with a focus on strengthened feedback and improvement measures" [32]. Once a participatory method is established, there are a variety of methods to work with problem solving. But it is precisely in complex and social problems that several perspectives are so important to include. For exactly the reasons mentioned above. But this is difficult, very difficult. If the city of Stockholm truly has the ambition to have the people of Stockholm focus, then they also need to be responsive, even if the group is still not buying in to the proposed change [33]. In the field of work science, methods have been developed for dealing with wicked issues, typically NIMBY kind of issues such as wind farms and the issue of wolves in Sweden. "Citizens assemblies" or other dialogue methods may work when issues are difficult to understand and strongly polarized. Three arguments for early anchoring are:

1. Better basis for decisions: A dialogue makes it possible to share views, experiences and knowledge between those concerned. The dialogue becomes a way to understand each other's perspectives.
2. The strategy becomes more long-term: When decisions are based on the experiences of several people and they have been part of the process, the chances increase that it will be accepted and appreciated in broad groups and can be more long-term.
3. People have the right to participate and influence their own surroundings and local environment: This argument rests on humanistic and democratic foundations and is actually sufficient to justify a quest for anchoring in the planning process. [33]

In research on so-called wicked problems [9] it is assumed that positive contributions are made by a common system description including actors' roles and responsibilities, which provides a good overview for managing complexity. Further, recommendations are to promote a learning approach and perseverance with an anchored view of a reasonable level of ambition for implementation. Finally, it is also important to have an awareness of various perspectives to improve communication skills. All this combined contributes to careful design of implementation and measures and well-functioning collaboration among a diverse set of actors and stakeholders. When questioning whether this type of preventive dialogue has had any real effects in truly wicked problems, one should consider that stakeholders will still have to spend many resources with the risk that the decisions will not be made anyway [8].

4 Analysis and discussion

From the problem formulation and brief information at hand on a UAM concept potential blockers from citizen acceptance perspective have been identified. Annoyance from drone noise being intermittent, a sleep disturbance and distracting. NIMBY – not in my backyard issues – over placement of vertiports services, especially from non-users. Annoyance from non-acoustic factors like disappointment of decision makers, frustration and anger and issues with acoustics and noise levels like misunderstandings over models, metrics and measurements. Aspects with influence over these potential blockers are noise mitigations, noise metrics development, studies on drone noise annoyance, health and well-being, democratic processes, citizens assembly, communication, and information of drones, keeping Stockholmers' focus, citizen involvement in planning and decisions, simulation of noise impact from UAM, UAM traffic model. Potential blockers from city and region deals with innovation capability like integration into a current transport "regime", goal directed planning process with built-in resistance, practice with incremental innovation, low competence of drones and UAM. Aspects with influence over these potential blockers are to assure Stockholm's ”disposal” over UAM, innovation capability development, drone traffic strategy, interoperability, UAM traffic model (dimension, fleet), UAM environmental quality norms, UAM environmental impact analysis, cost-benefit analysis and competence development.

Returning to the questions in the ConOps process there are gaps to develop a UAM concept enough for a decision to commit major resources to implement a UAM system. To get further two scenario ConOps are drafted with respect to goal trade-offs and innovation trade-offs. A full-scale scenario I and a small-scale scenario II (Table 2).

Table 2. Scenario I and II with trade-offs for goals and innovation

Scenario I - Full scale UAM	Scenario II - Small scale UAM
Goal trade-offs	
Contribute to national transport and climate goals Capacity to reduce and replace road traffic Market forces will be strong and contribute to goals for business and growth in the city and its region Increase environmental impact and consideration goals for quality of life, health and well-being will not be met. Significant noise impact and number of Stockholmers annoyed by noise will increase	Main contribution for societal needs to increase health and emergency services and other services improving citizens health, security and safety Less environmental impact, the less air traffic, the less aviation noise and annoyance Expected increased citizen acceptance Small market will not foster businesses and job opportunities in the city.
Innovation trade-offs	
Will fit models and tools assessing changes and innovation in goal-driven planning processes. Integration will be facilitated by a system that compare and may compete with public transport in capacity and price. Integration resistance from citizens and community due to impact and environmental cost it will have Market forces will be strong and contribute to businesses in the city and regional development Job opportunities and to be a user may reduce annoyance for some citizens	Societal acceptance will facilitate integration. More citizens may identify themselves as users and beneficiaries. A small contribution, if any, to transport challenges reduces chances of coming out good in goal-driven planning processes assessing capacity an economy of scale. Will not compare to other modes of public transport. Lack of large markets in city may hinder expansion for regional development and businesses.

The purpose of this study was to analyze UAM from the perspectives of the citizens and the city and identify potential blockers with respect to noise and innovation. By doing so many unknowns and unanswered questions came forth. It is also demonstrated that the system managing implementation would benefit the support of a comprehensive ConOps of various scenarios of UAM. For each ConOps scenario cost-benefit and trade-off analysis should support decisions and balancing between goals and develop strategy accordingly to implement UAM properly. This study is part of a larger project, developing a platform for noise simulations from drone concepts. In further development this may be advanced further to combine with traffic models and simulate noise impact for combined drone concepts or a UAM concept. Noise simulations may also be used to support citizen engagement in planning and decision, developing noise metrics and environmental quality norms. A support to dimensioning UAM that is acceptable with respect to noise, annoyance, health and well-being.

Table 3. The need for noise simulations in support for UAM ConOps

Needs for support development of UAM ConOps	Noise simulations as support to UAM ConOps
-Environmental impact analysis -Health impact assessment -Simulation of noise impact UAM -UAM traffic model (dimension, fleet) -UAM innovation capability development Balance global and local goals in planning -environmental impact with transport and business needs Adapt citizen in UAM planning and decisions Develop a UAM traffic strategy Continue cost-benefit analysis with UAM Con-Ops Develop drone noise metrics Develop UAM environmental quality norms	Communication with and education of citizens, city servants, politicians, operators and developers… Traffic strategy and noise environmental impact assessment Developing metrics Developing effective measures and mitigations Environmental impact analysis Traffic planning (vertiport nodes and routes) Policy development for noise mitigation incentives for developers and operators

5 Conclusions

This study aims to raise awareness, develop knowledge, and provide recommendations that will support stakeholders in the development and implementation of drones in urban environments. The recommendations to stakeholders are to adapt a similar “rich picture” and system description including relevant actors' roles and responsibilities and identify in detail development and planning processes. This provides a good overview for handling expected complexity when integrating drones in Stockholm. The identified risk that citizens will react with resistance is a worst-case scenario, but there is other evidence that working proactively with citizens is a good idea for sustainable and long-term solutions. By avoiding surprises, keeping promises, expand responsibly, develop competence in acoustics, noise levels for measurement and restrictions, simulate noise exposure, collaborate broadly by applying democratic processes may reduce annoyance as a non-acoustic factor and facilitate innovation. The rationale holds that a thorough problem formulation of this complex transition will increase the chance for success.

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