UAM innovation – a sustainable transition?

1 Introduction

Mission-oriented innovation policies are currently central in driving research and innovation agendas at an EU as well as at a national level. MIPs are argued to have benefits in addressing "grand challenges" (Mazzucato, 2018). The use of the word "mission" is borrowed from large-scale projects in an attempt to make an analogy to successful mission-oriented policies in the past like the Apollo program. The purpose is to set a mission and to assure top-down that everyone is working in the same direction towards a common objective. However, it seems like this is as far as Mazzucato wants to take this analogy. "Much of the success of the Apollo programme can be credited to its use of systems engineering and its sister discipline systems analysis" (Jackson, 2021), still methods for system analysis and problem solution developed and applied in these historic missions are discarded and criticized for their rational analysis.

The Swedish innovation agency of VINNOVA has produce a handbook (Hill, 2020) on how to design suitable missions. The handbook described these aspects to characterize a mission-oriented approach:

- Co-creation to understand and take on the challenge
- A mix of top-down and bottom-up
- Handles goal conflicts to meet complex societal challenges
- A common collection of forces with a bold objective
- Coordinated by actors with different roles in the system

This list acknowledges the best practice of managing complexity in large scale projects in systemic and systematic approaches to address trade-offs, which is considered "good" engineering praxis. So, the assumption is that the intention of approaches to systems thinking for various types of problems and solutions are very similar. VINNOVA make comparisons: "It may be enormously more difficult to design policies to equalize educational achievement…, than to design spacecraft to go to the moon. And in reference to the book The Moon and the Ghetto (Nelson, 1977 as cited in Hill, 2020) summarized as "The complex problems of ghetto will not line up neatly in linear fashion, as if simply complicated technical nuts to crack: even though it is the scientists who have chosen a career that allows them to pursue relatively simple problems as building a machine to detect gravitational waves rather than genuinely difficult ones such as running a social-care program in a small town.

From an engineering perspective this is confusing and may be read as a straw man argument to discharge engineering methods from the 60's for not being fit for the challenges of today. Obviously there has been advancements in systems engineering: system dynamics, modelling, and simulation (INCOSE, 2023) since then! I guess one needs to have run a social-care program, built a machine and lead engineering teams behind SAABs Jas-39 to be able to compare how problems line up. We know that engineering system solutions may contribute to meeting societal needs and still, as they scale and evolve over time, they will also give rise to emergent unintended consequences. It seems like the same system aspects are catching up with mission driven innovation policies.

The concept of "wicked problems" was coined by (Rittel and Webber, 1973) and described in 6-10 properties like complex causality, many stakeholders, chronic meaning that the issues cannot be solved etc. Wicked issues have also been described further in the MIP literature. Three dimensions of wickedness have been identified (Wanzenböck et al., 2020) and are summarized here:

- *contestation*, referring to the degree of normativity related to a policy issue.
- *complexity*, understood in institutional terms, is caused by the multi-scalar and multi-dimensional nature of societal problems to be addressed

- *uncertainty*, pointing to a lack of knowledge or limited availability of evidence to determine policies, for instance, related to the risks or damages of action and non-action, the specific relationship between causes and consequences of a problem, or the fragmentation of knowledge across different stakeholders about the (side-) effects of not tackling a problem

The purpose is to critically analyze the rationale behind mission-oriented innovation policy (MIP) and the ongoing development and push for urban air mobility (UAM). Cases have been developed from earlier projects in sustainable aviation with focus on aviation noise and annoyance. The first was about noise issues from commercial aviation and in particular around Sweden's largest airport Arlanda (Ulfvengren, 2023). The other project is still on-going studying integration and implementation of Urban Air Mobility (UAM) in Stockholm. This study asks: How are missions behind UAM development contextualized using dimensions of wickedness in a problem- solution space?

2 Method

Data has been collected through interviews, workshops, and documentation from stakeholders in the air transportation system, transport agencies and authorities, citizen noise organization, air traffic service providers, as well as the City of Stockholm and its Region, the Swedish Environmental Protection Agency and drone manufacturers' networks. The projects have had a broad approach that continuously engaged stakeholders through discussions with representatives of these stakeholders.

2.2. Re-visioning

Wicked problem formulation is argued to require a "rich picture" (Churchman, 1971) to allow externalities to be factored in. In both projects a problem formulating method from engineering systems was used called re-visioning (de Weck et a., 2015). Systems have evolved from artefacts like cars, light bulbs, and telephones to systems for transportation, energy, and communication. Today many of these systems have lost control over biproducts and unintended consequences, which today manifests as downsides for humans in societies globally as well as locally. To mitigate this new design methods called *system (re)thinking* or *re-visioning* has been developed (ibid.). A model supporting this rationale describes solution space, design space and problem space (Figure 1 and 2). 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 have associated problems which are represented in nodes in the problem space.

2.1 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 (Kossiakoff et al., 2011); Needs Analysis Phase: "Is there a valid need for a new system?" and "Is there a practical approach to satisfying such a need?" Concept Exploration Phase: "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: "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. Not until there is a satisfactory answer to these questions, a decision to commit major resources to the development of the new system can be made. For more details on the ConOps process used see Ulfvengren et al. (2024) and Fairley et al. (1994).

2.2 Three dimensions of wickedness and pathways through problem-solution space

For this paper readings have been complemented with literature on mission-oriented innovation policies and documents from EU commission and funding agencies on missions, strategies, and goals. The three dimensions of wickedness (Wanzenböck et al., 2020): *contestation*, *complexity* and *uncertainty* are used for further analysis of the case of UAM integration into Stockholm and its region and evaluation of MIP in relation to social concerns such as noise and annoyance with effects on citizens' health and well-being.

Table 1. A two-dimensional problem-solution space for contextualization of missions (from Wanzenböck et al., 2020)

	Divergent views on the problem	**Convergent views on the problem**
Divergent views on solutions	*I. Disorientation*	*II. Problem in search of a solution*
	High wickedness of the problem due to i. Broadly framed challenge ii. Lacking problem legitimacy and responsibility iii. Limited knowledge on problem nature	Wickedness of the problem reduced to i. Legitimized or shared vision ii. Clarity about political responsibilities to address problem iii. Advanced problem understanding and social learning
	High wickedness of the solution due to i. No shared vision on feasible solution, vague, and disputed ideas ii. Fragmented approaches and low willingness to cooperate iii. Limited knowledge on effects and side effects on innovations	High wickedness of the *solution* as in I
Convergent views on solutions	*III. Solution in search of a problem*	*IV. Alignment*
	High wickedness of the *problem* as in I	Wickedness of the *problem* reduced as in II
	Wickedness of the solution reduced to i. Concrete expectations on technological or institutional innovations ii. New business models and integrated appraoches iii. Claims of feasibility and societal impact of innovation	Wickedness of the solution reduced as in III, societal embedding limited

3 Results and analysis

3.1 Missions behind the drone strategy

The MIP approach has been adopted by the EU. Horizon Europe was presented by the European Commission (EC, 2018) with five established mission boards to help advance mission agendas. Their work resulted in the design of five mission areas involving cancer, climate adaptation, healthy oceans and waters, climate neutral and smart cities, and soil health and food.

The European Green Deal, followed (EC, 2019) "to transform the EU into a modern, resource-efficient and competitive economy, ensuring: no net emissions of greenhouse gases by 2050, economic growth decoupled from resource use and with no person and no place left behind". The "Green Deal" shows "the way on climate action and shape the green transition for the benefit of citizens and industries".

In 2020 the EC adopted a strategy for sustainable and smart mobility. To achieve climate neutrality, a 90% reduction in transport emissions is needed by 2050. Road, rail, aviation, and waterborne transport will all have to contribute to the reduction. Achieving sustainable transport means putting users first and providing them with more affordable, accessible, healthier and cleaner alternatives to their current mobility habits. The zero-emission ambition includes aviation and there are dedicated funding programs for "Clean Aviation" and SESAR for "Single European Sky".

The Commission chose to fund development for the EU transport system and infrastructure fit to support new sustainable mobility services that can reduce congestion and pollution, especially in urban areas. Transport should become drastically less polluting, especially in cities. A combination of measures should address emissions, urban congestion, and improved public transport... smart, environmentally friendly, and integrated urban transport.

The European Innovation Council will dedicate funding, equity investment and business acceleration services to high potential start-ups and SMEs for them to achieve breakthrough Green Deal innovation that can be scaled up rapidly on global markets. This has emphasized experimentation and working across sectors and disciplines.

In the "Sustainable and Smart Mobility Strategy" it is acknowledged that mobility brings many benefits for its users, but this is not without costs. Safety, noise and health and wellbeing are mentioned, and it is admitted that past efforts and policy measures have not sufficiently addressed these costs but ends the sentence with a reminder that the main issue is the transport sector's greenhouse gas emissions calling for zero emission engines. Again, it is acknowledged that this still does not solve issues raised by the use of tires, causing noise and microplastics.

The idea is clearly to resolve many wicked issues with this transformation, including businesses and that new solution will open up for new markets and jobs: "great opportunities for better quality of life, and for European industry across the value chains to modernize, create high-quality jobs, develop new products and services, strengthen competitiveness and pursue global leadership as other markets are moving fast towards zero-emission mobility".

The Commission also have a vision that will ensure that passenger transport-on-demand can become more sustainable and deliver efficient services to citizens while …. addressing social and safety concerns. The idea is that "people should enjoy a seamless multimodal experience throughout their journey, through a set of sustainable mobility choices, increasingly driven by digitalization and automation. As innovation will shape the mobility of passengers and freight of the future, the right framework and enablers should be in place to facilitate this transition that can make the transport system much more efficient and sustainable."

From this the Commission fully supports deployment of drones. The 'Drone Strategy 2.0' (COM, 2022/652) states a vision of a large-scale European drone market. It is described as a perfect concept for a "twin green and digital economy" and follows a breakdown and a rationale from two mission areas: climate adaptation (of transport) and climate neutral and smart cities. The main objective is therefore to further develop the EU drone strategy in light of the European Green Deal, Smart and Sustainable Mobility Strategy, and Digital Strategy. However, this includes for example the set "targets and actions on how clean the new EU transport policies should be, for instance on noise and air pollutants". In communicating the drone strategy, it is suggested that the "social benefits of drone operations should be highlighted as they would justify support from national and local public authorities to further their development".

It is clear how these ambitions are followed on a national basis. The Swedish government has issued assignments to agencies in Sweden within the aviation sector for example the Swedish Transport Agency (Regeringen, 2023). The purpose is "to strengthen conditions for a competitive drone industry in Sweden and EU, and facilitate a safe, sustainable, and efficient use of drones, with concern for national conditions and potential common or individual interests.

From EU level support is also put in to facilitate a bottom-up innovation process enabling environment for such game-changing mobility technologies. The EU aims to become a prime deployment destination for innovators, for example in enabling an agile regulatory framework that start-ups and technology developers need to pilot and deploy their products on the market.

3.1.1 Drones and noise

The climate action is designed to shape the green transition for the benefit of citizens and industries, and this means putting the users first and providing them with more affordable, accessible, healthier, and cleaner alternatives to their current mobility habits. How these targets will be managed is not further discussed in the documents. However, in a staff work document there is a section addressing noise that shows there exist awareness: "It is important to note that amongst the three main pollutants of road transport (CO_2, noise and air pollutants), reduction of CO_2 emissions imply air pollutants reductions as well, thus constituting an additional benefit. This is not the case for noise, that needs specific other technological solutions to be implemented together with the CO_2 emissions standards. Zero-emission vehicles can still emit the same noise levels as traditional combustion engine ones." (COM 789, p248, 2020).

When it comes to drones EASA (European Union Aviation Safety Agency) has shown that safety and noise pollution are on top of EU citizens' concerns among other issues of cybersecurity risks and the potential impact on wildlife (EASA, 2021). It is therefore concluded that are many other issues beyond safety that must also be addressed in order to ensure the social acceptance of drones, such as environmental and privacy issues.

3.2 The case of aviation noise around Arlanda

In earlier research a system analysis was performed with an ambition to get a "rich picture" by understanding various networks of problems associated with aviation noise. Several dilemmas and goal conflicts were identified in relation to fore example: housing strategies at national and municipal levels, different areas of responsibility among civil servants such as environmental department concerning citizens health and well-being and the department responsible for municipal growth and businesses. In short, the municipals want to expand and build housing which means building closer to the airport. The airport is contributing as a large employer among citizens in neighboring cities. On the other hand, citizens around the airport are exposed to aviation noise which has severe health effects and effect quality of life and well-being. Community complaints have been filed and won. The environmental permit comprises over 10 conditions today restricting airport operations with respect to noise exposure.

Somewhat simplified, there is no solution to aviation noise. Well, yes, to fly less. It is not a technological problem and does not have a technological solution; noise is governed by the laws of energy conservation. With its speed and mass an airplane needs to slow down to descend and land safely. In the approach and landing phase it is not the engine that is the main sound source, it is the airframe and everything at hand to slow the aircraft down, not least the landing gear. So increased traffic will increase aviation noise and the more citizens exposed the more annoyance affecting health and well-being. Hence aviation noise is a truly wicked problem!

A re-visioning of commercial aviation (Figure 1) was performed from three main network of problems associated to aviation noise issues (Ulfvengren, 2023): 1. Neighbors exposed and annoyed by noise, 2. Service providers and operators challenged with development and innovation, and 3. Actors that govern and control air transport with respect to transport and societal goals.

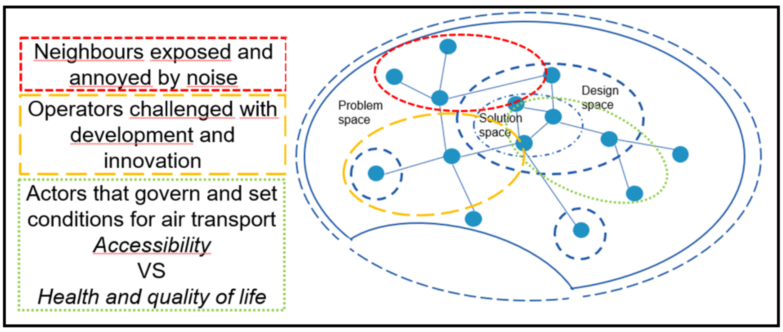

Figure 1: Network of problem formulations in commercial aviation (from Ulfvengren, 2023).

Linked to missions of climate adaption and initiatives such as "Clean sky" the aviation industry is undergoing a large transition to more sustainable fuels and electric aircraft. At a recent governmental hearing for the investigation of the future of Arlanda (Ulfvengren, 2023), it was made clear that not only current but also future aviation industry is still anticipating and planning for an increase of air traffic world-wide. Hence aviation noise will increase.

3.3 The case of integrating UAM in Stockholm

Understanding the wickedness of aviation noise issues has inspired the case on drones and UAM integration in Stockholm city and regions (Orrenius et al., 20204; Ulfvengren, 2024). UAM is a radically new type of transport system depending on its ability to land and take-off vertically and fly point-point. Noise is often mentioned, and it is acknowledged as part of an overall concern for societal acceptance of drones in an urban environment. We can learn from experiences and evidence of community complaints in commercial aviation. With drones there will be noise, under the same laws of physics but with differences due to design.

A re-visioning of UAM development (Figure 2) was performed from three main network of problems associated with aviation noise issues (Ulfvengren et al., 2024). 1. Stockholm citizens, 2. City (municipality) and regional planning, and 3. Service providers and technology developers and operators.

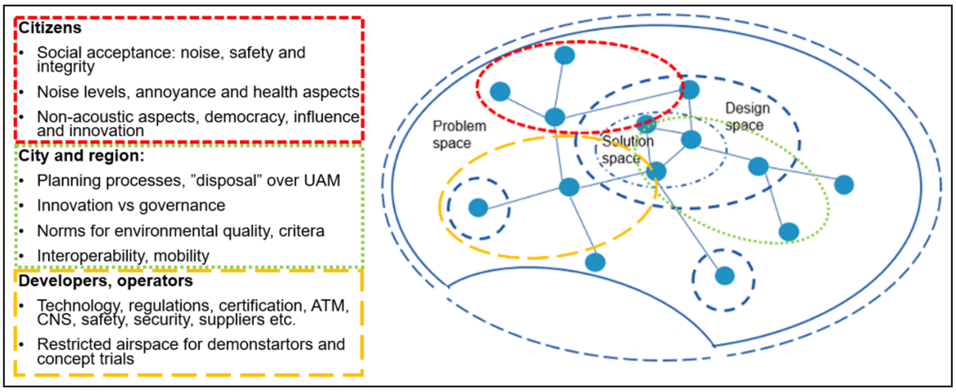

Figure 2: Network of problem formulations UAM development (from Ulfvengren et al., 2024).

Development of UAM links to missions of Climate adaptation and Climate neutral and Smart cities and has directed strategies for Sustainable and Smart Mobility Strategy, Autonomous vehicles, Mobility and its own “Drone Strategy 2.0” with a vision of a large-scale European drone market. If drones are to contribute to the climate goals it is reasonable to assume that an UAM will replace some of the traffic and be part of public transportation. Further it can be assumed that considerable traffic will be required for UAM to be affordable and seamlessly accessible. To analyze goals and clarify trade-offs ConOps were used which resulted in two initial scenarios (table 2). Depending on the scale of UAM it shows differences in alignment between goals at various levels and wicked issues that need to be managed.

As part of the mission there has also been funding and support dedicated to developers, start-ups and operators to test and come up with concepts as well as facilitating regulatory frameworks and support to deploy products on the market. 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 (Euronews, 2022).

There are also non-acoustic factors (Porter and Monaghan, 2021; Leylekian, 2020) 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. There is an increased emphasis on

Table 2. ConOps applied to UAM. Two scenarios and goal trade-offs (from Ulfvengren et al., 2024).

ConOps I – Full scale UAM	ConOps II – Small scale drone service
Contribute to national transport and climate goals	Main contribution for societal needs to increase health and emergency services and other services improving citizens health, security and safety
Capacity to reduce and replace road traffic	Less environmental impact, the less air traffic, the less aviation noise and annoyance
Market forces will be strong and contribute to goals for business and growth in the city and its region	Expected increased citizen acceptance Small market will not foster businesses and job opportunities in the city.
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	

citizens' quality of life presented through the European green deal (COM, 2019) which also puts emphasis on democratic processes. Local resistance and community complaints are therefore expected. In a worse case, this will lead to community complaints, delay of permits, restrictions, and rather foster drone resistance rather than drone acceptance. This will, if not managed "properly" have a potential negative effect on business, which means this should be of great interest to developers and operators of UAM (Ulfvengren et al., 2024). This has allowed drone concepts to flourish. Table 3 shows a summary of recent concepts under development (Ulfvengren et al., 2024).

Table 2. Drone concepts identified in APIS project (Ulfvengren et al., 2024)

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

3.4 Problem and solution led-pathways of innovation for UAM

Some clearly believe that UAM will contribute to climate goals for transport and significantly replace road traffic to reduce congestion and improve mobility seamless and affordable. But when it comes to addressing societal acceptance and noise issues there is a belief that there is a technological problem and solution to noise. Here those that believe in UAM climate opportunities since it is fossil-free agree with those that believe in mobility with aviation point-to-point. Among these noise and local environmental issues has no priority and is marginalized. Nowhere is there for example a discussion of that UAM will be supported only if it can demonstrate that it also contributes to reduce noise in the city. Overall, there is no metrics or criteria for balancing local and global environmental impact. How much well-being and health effects is carbon reduction worth for this particular mission?

There is no doubt that there is great consensus of the need to reduce carbon emissions from transport. There is also a dominant definition on challenges with urbanization, congestion on roads and capacity limits of public transport. Agreements seem to converge also that this is solvable with smart and sustainable transportation. We are supposed to continue to grow cities and business at the same time increase travel but with improved health and well-being, despite the known cost of transport, where noise is the same for electric or fossil-driven vehicles, aircrafts and drones.

So, there seems to be a dominant definition and optimistic expectation on the link between the missions linked to drones, like mobility, autonomous vehicles, smart cities and the fossil-free economy. And even if noise issues and other aspects for societal acceptance are mentioned, it is not pessimistic to the drone solution. The societal impact is, however, known and there is great uncertainty, given the fact that we cannot even ask people what they think, since the system does not yet exist. When regulations and infrastructure exist, there is perhaps a steep curve to growth, given the network structure of flying point to point. It can become many drones with only a few successful concepts. This may become self-regulating with community complaints. However, there is a risk that this also ruins the opportunity for an acceptable small-scale system with great societal benefits.

In summary the many perspectives and stakeholders in UAM integration shows that it depends much on how you balance the expectations with the risk, and how well decision makers understand how noise and aviation work. So it is suggested to do a deeper analysis, for each networks of problem and stakeholders from the re-visioning in figure 2 and table 1.

With this initial analysis it is clear that if you see noise as a severe aspect for both health and well-being as well as for realizing UAM then this may still be in Quadrant I- *Disorientation*. If noise is considered less costly and something that will be possible to solve then this drone mission is in quadrant II-*Solution in search of problem*.

Problem statements diverge if accepted knowledge on a problem is lacking, the division of responsibilities to address the problem is unclear or institutional complexity is high (ibid.). In contrast, problem statements converge when there is an agreement of framing and its relative importance (ibid). In their work they see these dimensions as a way to conceptualize MIP further and also to raise awareness when MIPs due to various wickedness may fall for unintended “taming” of issues.

Very little indicates Quadrant IV-*Alignment,* which in this case gives some hope that there is not taming of issues, but enough interest of understanding trade-offs and continue to work on problem formulation to avoid unintended consequences.

4 Discussion and conclusion

MIP often refers to wicked problems to solve societal problems. But what is it that makes complex societal issues so difficult to resolve? Why are we not better at managing them? This type of questions was posed by (Jordan et al., 2013) who argue that one simple answer is to conclude that *some* does not seem to resolve or manage what *others* perceive as urgent issues and that even good intentions from one party may have unintended consequences on another. Really understanding complex matters requires understanding many and different perspectives (Jordan and Andersson, 2010).

From a systems and engineering perspective, best practice was applied by performing a system analysis and frame problems sufficiently to assure understanding of what choices are being made, what is prioritized and why. This paper is based on two case studies, one from commercial aviation context and one from on-going development plans for integrating and implementing UAM.

Wanzenböck et al. (2020) argue that by “disregarding the “degree of wickedness” involved in a particular challenge, the innovation policy literature runs the risk of providing a one-size-fits-all approach for MIP, with taken-for -granted problem definitions and too strong emphasis on technological innovation, while marginalizing opposing voices or discarding complex trade-offs”.

The “Drone mission” precipitate unintended consequences and lead way for investors and developers to promote UAM as an innovative fossil-free transport economy on several on-going innovation pathway through a problem-solution space with high divergence in three dimensions of wickedness.

Earlier parts of this research have identified challenges in managing the complexity of aviation noise to be messy and as a wicked problem. Wicked problem formulation is argued to require a “rich picture”. Similarly, MIPs need to factor in externalities already in design of missions to avoid surprises with undesired and unintended consequences. This is especially important when there is no optimal solution to the problem.

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