

CRANFIELD UNIVERSITY

Aaron John Organ

Creating a Framework for Community Integration of Urban Air
Mobility

Transport Systems
MSc by Research

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Academic Year: 2020 - 2022

Supervisor: Professor Keith Mason, PhD
Associate Supervisor: Henrik Rothe
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ABSTRACT

Technological advancements in propulsion systems, alternative fuel, battery power and storage, and autonomy have led to the development of a new generation of aircraft. These enabling technologies inclusive of Small Unmanned Aircraft Systems (sUAS), Large Cargo Unmanned Aircraft (LUCA), and electric Vertical Take-off and Landing (eVTOL) or electric Conventional Take-off and Landing (eCTOL) aircraft fall under the umbrella term of Advanced Air Mobility (AAM). The current literature, in addition to regulators and the industry, is heavily focused on the aircraft and technology integration. This research contributes to a literature gap concerning ground infrastructure and community integration of AAM. The research aims to provide a framework of next steps relevant to state and city planners and policy makers.

Subject matter experts from key AAM stakeholder groups were consulted through the execution of semi-structured interviews to produce a rich dataset of the issues and challenges of integrating AAM into the state and city's transportation systems. The systematic approach of thematic analysis was used to identify top themes and sub-themes. The results identified AAM success keys, potential use cases, anticipated benefits of AAM, anticipated obstacles to AAM adoption, and stakeholder roles at the city, state, and federal level. These results have provided a framework for cities and states of what to do in the initial phases to integrate Advanced Air Mobility technologies into their existing transportations networks for a more sustainable and robust system.

Keywords:

Advanced Air Mobility (AAM), Electric Aviation, Electric Vertical Take-off and Landing (eVTOL)

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LIST OF ABBREVIATIONS

AAM	Advanced Air Mobility
AC	Advisory Circular
AD	Airworthiness Directive
AIP	Airport Improvement Program
BVLOS	Beyond Visual Lines of Sight
CFR	Code of Federal Regulations
DOT	Department of Transportation
eCTOL	Electric Conventional Take-off and Landing
EPU	Electric Propulsion Unit
eVTOL	Electric Vertical Take-off and Landing
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
GAMA	General Aviation Manufacturers Association
IFR	Instrument Flight Rules
LUCA	Large Unmanned Cargo Aircraft
MPO	Metropolitan Planning Organization
NASA	National Aeronautics and Space Administration
NAS	National Airspace System
NPIAS	National Plan of Integrated Airport Systems
OEM	Original Equipment Manufacture
PAV	Personal Aerial Vehicle
PFC	Passenger Facility Charge

RAM	Rural Air Mobility
SAR	Search and Rescue
SME	Subject Matter Expert
STC	Supplemental Type Certificate
sUAS	Small Unmanned Aerial System
UAM	Urban Air Mobility
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UTM	Unmanned Traffic Management
VFR	Visual Flight Rules
VMT	Vehicle Miles Travelled

1 Introduction

1.1 Background

The aerospace industry is currently faced with the opportunity to integrate emerging technologies that could secure a more sustainable future and open completely new markets and roles for air transport. Advancements in electric-powered engines, battery systems, propulsion systems, use of hydrogen fuel, tiltrotor and tiltwing designs, composites, unmanned aircraft systems, autonomy technology, and more are enabling the development of aircraft that open the door to new use-cases. The amelioration of these technologies is creating a new movement and industry within the greater aviation industry called Advanced Air Mobility (AAM).

Throughout the last century the terminology describing various applications of air transportation has changed, these various terms will be further explored throughout this work. The term Advanced Air Mobility, or AAM, is a broad and inclusive term of the numerous progressing technologies. The United States National Aeronautics and Space Administration (NASA) released the following statement in March of 2020:

“NASA’s vision for Advanced Air Mobility (AAM) is to help emerging aviation markets to safely develop an air transportation system that moves people and cargo between places previously not served or underserved by aviation – local, regional, intraregional, urban – using revolutionary new aircraft that are only just now becoming possible. AAM includes NASA’s work on Urban Air Mobility (UAM) and will provide substantial benefit to U.S. industry and the public” (Banke, 2020, para. 1).

AAM serves as an umbrella term over the up-and-coming technologies and the recent progress being made across the industry has led to a timely revival of the focus on urban and regional air transportation. AAM can be a key piece of a sustainable transportation system as the existing U.S. transportation infrastructure continues to crumble. The 2021 State of United States Infrastructure report noted that the U.S. infrastructure is dangerously stretched

and lags significantly behind its peer nations (McBride & Siripurapu, 2021). The population has doubled in the United States compared to about 50 years ago, this has led to traffic congestion delays costing the economy over \$120 billion per year (McBride & Siripurapu, 2021).

On a global scale, commercial aviation operations accounted for 918 million metric tons of CO₂ emissions in 2019 which was an increase of 29% from 2013 (Graver, Rutherford & Zheng, 2020). Aviation contributes 12% of the total transportation CO₂ emissions (“Facts and Figures”, 2020). There is a global movement for not only a cleaner, more environmentally friendly air transport industry, but a more sustainable transportation system overall.

As key United States transportation infrastructure continues to age and traditional aviation continues to work towards decreasing emissions, the technologies of AAM present various opportunities to greatly assist in solving these issues. But perhaps the greater problem is how are AAM technologies to be integrated into city and state transportation systems? This research seeks to address this larger problem.

Companies, regulators, and the literature are heavily focused on the technology aspect of the AAM movement. While there is focus on the aircraft, airspace integration, Unmanned Traffic Management, and concepts of operation there appears to be far less attention on the necessary ground infrastructure and the community integration of AAM. This research will discuss the technology components and reference new aircraft as examples of electric vertical take-off and landing (eVTOL) and electric conventional take-off and landing (eCTOL) aircraft but overall, this research will remain aircraft agnostic when discussing AAM aircraft integration. While there are studies that analyse which emerging aircraft may be the best, that is outside of this research scope. Remaining aircraft agnostic allows for the focus to be set on the established research aim and objectives as outlined in section 1.2.

1.2 Research Aim and Objectives

The overall aim of this research is to develop a framework of next steps that will provide utility to city planners, transportation planners, aviation planners and to municipality and state governments seeking to integrate Advanced Air Mobility into their communities and regions. While global statistics and examples are referenced the scope of this research is mainly focused on the United States as that is where the author resides and is employed. To meet the research aim the following research objectives of this thesis are:

- **Analyse the current state of the literature and contribute to the literature gap on AAM community integration**
- **Identify local stakeholder roles concerning integration of AAM**
- **Identify the keys necessary to successfully integrate AAM into local transportation systems**
- **Identify potential use cases and anticipated consequences of AAM**

1.3 Thesis Overview

This thesis was approached in a traditional research manner by performing a review of the literature regarding the topic, identifying a literature gap, developing research objectives to contribute to the literature and industry, and then executing original primary research. Below is an outline of the chapters contained herein.

Chapter 2: Background and Literature Review

Advanced Air Mobility is a recent umbrella term capturing the progressing technologies that will enable new markets in the aviation industry or potentially revolutionize existing markets. Chapter 2 provides a thorough background and analysis of the current literature and current state of the industry of five key categories which are Small Unmanned Aircraft Systems (sUAS), Large Unmanned Cargo Aircraft (LUCA), Electric/Hybrid propulsion technologies, Regional/Rural Air Mobility (RAM) and Urban Air Mobility (UAM). This chapter presents the history behind some of these technologies and the historical potential of urban air travel of the past providing necessary context for the current

movement. The review of the literature identifies top obstacles to overcome for successful adoption of AAM, in addition it reveals the literature gap where this research contributes.

Chapter 3: Methodology

The chosen methodological approach for this thesis was thematic analysis. Chapter 3 identifies various qualitative research methodologies and discusses the advantages of thematic analysis while establishing why it was the best systematic approach to meet the research objectives. This chapter will outline in detail the thorough and robust process that was used to conduct semi-structured interviews with Subject Matter Experts (SME) and the subsequent data analysis which resulted in key themes and sub-themes.

Chapter 4: Results

The thematic analysis resulted in a rich dataset that provided the opportunity for a thorough examination of the data to identify the fundamental themes and sub-themes. In Chapter 4, five main themes, each containing three to five sub-themes are presented and extensively discussed.

Chapter 5: Conclusion

The concluding chapter presents the four research objects and discusses the findings that met these objectives and accomplished the overall project aim. Limitations of this research are explained and the opportunities for future research outlined.

2 Background and Literature Review

2.1 Literary Scope

For the purposes of this research AAM has been broken down into the following categories: Small Unmanned Aerial Systems (sUAS), Large Unmanned Cargo Aircraft (LUCA), Electric/Hybrid aviation, Regional/Rural Air Mobility (RAM) and Urban Air Mobility (UAM). An important note is the use of “Unmanned” throughout this thesis, rather than “Uncrewed”. Within the majority of the literature, especially American literature, the use of “Unmanned” is still widely used and accepted. In Spring 2022 the United States Federal Aviation Administration began reviewing the recommendations from the Unmanned Aircraft Systems Beyond Visual Line-of-Sight Operations Aviation Rulemaking Committee. One of these recommendations is to adopt and use the gender-neutral term “Uncrewed”, but at the time of this writing, it has yet to be adopted.

There tends to be some cross over between some of these five categories and these five categories are not inclusive of all the possibilities that fall under the AAM umbrella. For example, there are many Personal Air Vehicles (PAVs) concepts currently under development but within the scope of this work only the five categories above were explored. The main focus of this research is on urban air mobility as it has the potential to have the greatest impact on passenger air transport systems. Below in Figure 1 is a visual representation of the literary scope branching from these five categories. In the following sections the history and current use of sUAS, LUCA, RAM and electric/hydrogen propulsion are considered before a more in depth focus for the rest of the chapter on Urban Air Mobility.

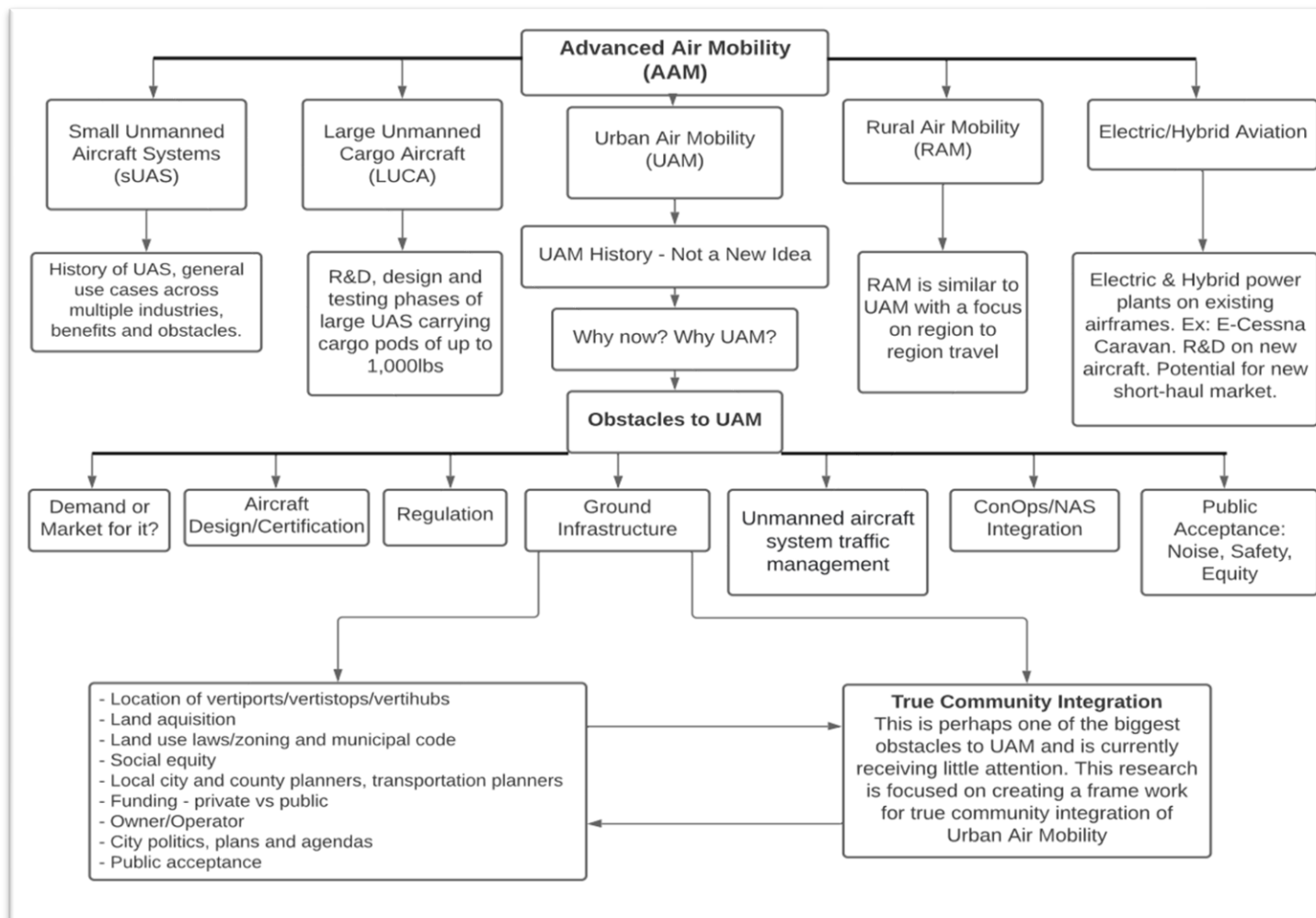


Figure 1: Literary Scope (Author)

2.2 Small Unmanned Aerial System (sUAS) History

Unmanned Aerial Systems (UAS) is a growing industry with a plethora of commercial and hobbyist use cases. Unmanned Aerial Vehicles (UAVs) or drones are by definition an aircraft with no pilot on board, these aircraft can be remotely controlled. Many new ideas and technology are initially developed, tested, and used in military forces prior to becoming available to civilians, UAVs are no exception. The first pilotless aircraft were invented during World War I by the British military in 1917 flying what was called the Aerial Target and in 1918 by the United States military testing the Kettering Bug (“A Brief History of Drones”, 2020).

In 1935 the British developed the “Queen Bee” which was used as a remotely controlled target drone meaning it was used as the target for pilots to shoot down in military practice exercises. Throughout the 1930s over 15,000 different target drones were produced and used in military training (Vyas, 2020). During World War II the technology took a big leap for both manned and unmanned aircraft. For example, advancements took place in range, speed, and accuracy. By the Vietnam War in the 1960s-1970s drones were being deployed on reconnaissance missions and other operations were being tested such as using drones for precision bombing. UAS advancements continued throughout the Gulf Wars of the 1990s and on to present day with the United States military maintaining a \$7 billion budget for drones and related expenses (Alkobi, 2019).

In 2006 the Federal Aviation Administration (FAA) created the Unmanned Aircraft Program Office with the goal of integrating commercial drone use into the National Airspace System (NAS) (“Unmanned Aircraft Systems (UAS) Certification Status”, 2006). In 2011 the FAA estimated the use of 30,000 drones in the NAS by 2020, although this did not come to fruition it demonstrates the vision of the leading air transportation regulatory agency (Busting Myths about the FAA and Unmanned Aircraft—Update, 2011). Leading into the Fall of 2016 only 13 permits had been approved by the FAA for commercial drone operators. This drastically changed in 2016 with the creation of Federal Aviation Regulations

Part 107, following the passage of this new regulation the FAA began issuing thousands of permits each year (Alkobi, 2019). The vision and approach of the FAA for UAS and other AAM disrupters for the coming years was released in June of 2020 within the Concept of Operations for Urban Air Mobility (UAM) 1.0 document. The aviation regulatory environment uses the “crawl-walk-run” approach, in the eyes of the FAA Part 107 enabled the crawling phase. While the industry may feel held back by regulation, they continue to rapidly find novel ways to employ UAVs under the current Part 107 rules.

2.2.1 Drone Regulation – Part 107

Part 107 Small Unmanned Aircraft Systems defines small UAS as anything that weighs 55 pounds or less at take-off including the aircraft itself and its payload. Part 107 rules outline the requirements of small UAS registration, remote pilot certification requirements, and all operational and safety regulations associated with UAS flight. One of the more well-known safety regulations of Part 107 is the restriction of Beyond Visual Line-of-Sight or BVLOS operations. This requirement means that all UAS operations must be done within eyesight of the Remote Pilot in command at all times from take-off to landing (“Title 14 Code of Federal Regulations - Part 107”, 2016). Although restrictions, such as no BVLOS operations, exist within the current UAS rules the passing of the Part 107 regulation did enable tremendous growth in both commercial use and recreational use of drones. At the beginning of July 2021, the FAA reported 870,823 drones registered in the United States and 236,576 Certified Remote Pilots (“Drones by the Numbers”, 2021).

2.2.2 Industrial Applications of sUAS

There are numerous ways in which drones are used in diverse industries throughout the world, in this section examples of sUAS applications are explored. Some of the overall goals of harnessing UAS technology are to complete tasks more efficiently, reduce labour costs, remove people from dangerous work or areas, and create additional productivity. There are additional goals about ensuring equity and accomplishing jobs in a more environmentally responsible way. Merkert and Bushell organize general drone use cases into the following

categories: monitoring/inspection/data collection, photograph/image collection, recreation, and logistics (2020).

Monitoring, inspection, and data collection casts a wide net over a myriad of ways UAVs are being used in several industries. Both large- and small-scale agriculture operations use drones to collect data that contribute to making a host of decisions. For over five decades satellite images have been used in providing this data, but using UAVs equipped with multispectral sensors is proving to be cost effective in providing higher calibre data (Lee et al., 2017). Farmers around the world use drones as a tool to analyse their soil, the health of crops, and growth patterns to make informed decisions on watering and fertilizing strategies. Drones are also used in planting with some systems claiming an 85% reduction in traditional planting costs. UAVs are also used in pesticide application where chemicals penetrating groundwater is reduced and execution completed up to five hours faster (Ahirwar et al., 2019). The mining industry uses this technology in similar ways. One of the main goals for mining companies is to maximize their production process, they do this by aerial monitoring of soil, stockpiles, leech fields, and blasts analysis (Bamford et al., 2017).

Utilization of unmanned aircraft and a variety of sensors to complete inspections is one of the larger use cases across industries. One of the main objectives for drone use is to remove humans from dangerous environments. For instance, historically high voltage power lines were inspected by linemen which has proven to be extremely hazardous and ineffective. Adoption of UAVs to complete these inspections by utility providers is becoming increasingly common (Li et al., 2018). Other energy alternatives such as wind turbines and solar farms complete equipment examinations the same way. Pipeline networks and cell providers also employ drones to complete their necessary inspections (Merkert & Bushell, 2020). In November of 2020 the Federal Transit Administration released a report titled "Use Cases for Unmanned Aircraft Systems in Public Transportation Systems". The report found that using UAS in track and infrastructure inspections as well as in emergency response result in increased efficiency and safety

(Wishart et al., 2020). There are a host of additional inspection applications such as roads, bridges, high-rise buildings, airports, construction sites, and others.

Often an early adopter of new technology following the military is the public service industry, for example: police, fire fighters, search and rescue and general emergency response. This has been true for the use of Unmanned Aircraft Systems. In 2015 one of the first noted police uses of UAVs was the Illinois State Police departments began using drones to get the bird's eye view of traffic accidents. In 2015 there were only about 100 law enforcement agencies using UAVs, this number has grown to 1,578 agencies as of March 2020 (Gettinger, 2020). Police departments around the world use drones to map out the city, pursue suspects, crime scene investigation, transportation accident investigation, traffic management, and other public service support (Rice, 2019). Officers also appreciate the aerial surveillance and the critical situational awareness that can be provided in tactical situations such as serving warrants, compound raids, and hostage circumstances (Nataliia, 2019).

In addition to emergency response, another pioneering area for using drone aerial support is in Search and Rescue (SAR). In 2015 an innovative study of the time was completed by Hakon Abrahamsen to test the use of a remotely piloted aircraft and its potential uses in five unique emergency response simulations. This feasibility study included the use of a custom-made multi-rotor drone equipped with cameras, thermal imaging sensor, a mechanical arm, a laser, and an avalanche search and rescue transceiver. The five simulated emergency situations in this study were: a multi-vehicle traffic accident, a mountain rescue, a snow avalanche, a fisherman falling through ice, and searching for people in the dark (Abrahamsen, 2015). The UAS was used to respond to each of these simulated emergencies while acting in varying capacities to test its different capabilities. The study concluded that UAS could serve in multiple functions during emergency response and SAR operations. Limitations were noted that have largely been minimized as the technology has matured over the last five plus years. For example, operational restrictions such as inability to hover in moderate wind, low battery life, and payload capacity.

Research on how to best utilize UAVs in SAR continue. In 2017 a simulation study was conducted to directly compare a Drone-snowmobile Technique (DST) to the Classical Line Search Technique (CLT) regarding mountain search and rescue (Karaca et al., 2018). In the experiment twenty simulations were run in which a real-life sized and clothed mannequin was hidden from the recovery teams to represent an unconscious victim. In the traditional CLT method five trained SAR individuals would spread out in a search line and proceed slowly walking forward and looking for the unknown location of the mock victim. At the same time a team of three using the DST method would deploy a drone to search for the missing mannequin. The two teams were evaluated in two stages: first to find the missing person and second to reach the victim. The average arrival time to the simulated victim was 57.3 minutes for CLT versus 8.9 minutes for DST. In many of the scenarios the drone was able to search an area more than double what the foot team was able to cover and did so in a fraction of the time. In SAR operations time is critical so to be able to significantly broaden a search area and cover it in a shorter amount of time will increase the survival odds of the victim.

In 2019 another study was completed evaluating the abilities and limitations of thermal drones in different SAR scenarios. Six searches were conducted using a drone, all six simulations were based on past real-life events. The payload of the drone was Thermal Infrared (TIR) sensors which allow warm human bodies to stand out in their environment, showing brighter on the display. The study explored in detail the abilities of the TIR comparing human temperatures to the environmental background temperatures. In conclusion the powerful utility of thermal sensing UAVs in search and rescue operations was demonstrated having successfully quickly located the lost individual in each simulation. TIR can see great distances through adverse weather conditions such as snow, fog, mist, and rain. This thermal detecting technology is being widely adopted as a prime tool for UAS search and rescue missions (Burke et al., 2019). The three previous studies have all relied on hands-on human manipulation of the remote controls of the UAVs. But current research is focused on machine learning or deep learning that would enable UAS to conduct fully autonomous surveillance in SAR operations (Mishra et al., 2020).

Just as studies have continued to increase, so have real world applications of UAS deployment in SAR operations. Over the last five years the annual people saved by the use of a drone has increased in the hundreds each year (“How Drones Are Reshaping the Future of Search and Rescue”, 2019). It is reasonably anticipated that these examples of lives saved using UAS technology in SAR missions will exponentially grow in the coming years as regulation allows for more optimal UAS-use such as BVLOS operations.

The summer of 2021 presented one of the worst droughts in the western United States that has ever been seen. As public awareness of the drought has grown so has the awareness of a closely related issue, the issue of wildfires. Wildfires across the United States have steadily increased in frequency and intensity over the last 40 years (Amadeo, 2019). In the year of 2018 alone 58,083,000 forest fires burned over 8.8 million acres (“Facts + Statistics: Wildfires”, 2021). In that same year the state of California saw the deadliest fire in state history. The “Camp Fire” burned over 153,000 acres, destroyed almost 19,000 structures, took 85 lives, and cost over \$16.5 billion in damages (Amadeo, 2019).

Significant amounts of research are being done on the various ways UAS can be used to help prevent, monitor, and fight wildfires. Perhaps the two most important things in the effort to minimize the damages of a wildfire are first the response time of firefighters from the time the fire ignites, and second is information on the severity of the fire to inform a proper response and fighting strategy (Akhoulfi et al., 2021). One of the initial uses of UAS concerning forest fires was post fire evaluation but now studies continue to be done exploring uses to prevent, detect, or actively assist in firefighting (Ollero et al., 2006). One of the main traditional methods for wildfire detection is using satellite images which presents issues such as resolution quality, limited coverage, and poor reporting times (Marder, 2019). UAS are proving to be viable tools for the task of detection due to their versatility regarding sensors, relative low cost, easy deployment, and autonomy (Akhoulfi et al., 2021).

Even in seemingly simple tasks UAS immediately offer a lot of value in wildfire fighting. For example, sending up a single drone to hover in a fixed point to

provide a live stream video to Incident Command of the fire provides tremendous value allowing for ground crews to properly plan containment strategies (Akhroufi et al., 2021). Research is showing how coordinating a fleet of drones to autonomously monitor large coverage areas allows for the collection of data leading to fire analysis, estimating growth patterns, predicting fire movement, etc. (Ghamry et al., 2016). Additional studies are exploring deep machine learning that could lead to the coordinated use of automated drones communicating with automated unmanned ground vehicles in actively fighting fire (Akhroufi et al., 2021).

Clear examples were provided on search and rescue operations and wildfire fighting operations, but these are two examples of many general emergency response uses of UAS. Drones have been used in or are currently under research studies to implement their use in the following emergency response situations: hurricanes, earthquakes, flooding, mudslides, hazmat response, structural fires, and others. Applications include: “recognition and mapping, structural integrity analysis, temporary delivery of groceries and parts of infrastructure, detection and fire extinguishing, fire response in high-rise buildings, chemical, biological, radiological, nuclear or explosive events, search and rescue operations and risk assessments and logistic support” (Correia et al., 2020).

Along the lines of emergency response there have been studies exploring the use of drones to deliver automatic external defibrillators (AEDs) to those who are experiencing Out-of-Hospital Cardiac Arrest (OHCA). About 1 million people die each year in United States and Europe as a result of OHCA (Hazinski et al., 2015). Data shows that response time is key to increasing survival rates of OHCA victims; for each 60 seconds that passes without resuscitation or defibrillation death rates increase by about ten percent (Hasselqvist et al., 2015). AEDs have proven to increase survival to hospital discharge by up to five times, unfortunately only five percent of people know where to locate and how to use an AED (Mermiri et al., 2020). This issue has led to research on how drones can increase response time to OHCA victims and how they can also provide real-time instruction to bystanders on how to use the AED being delivered. UAVs can be sent manually

or automatically using Global Positioning Systems (GPS) straight to the site of an individual under cardiac arrest where it can drop deliver or land and deliver an AED (Claesson et al., 2016). The individual(s) standing by who called for emergency response can then actively receive instructions through video or audio equipment on the drone on how to properly use the AED on the victim while waiting for paramedics to arrive (Mermiri et al., 2020). In another study done to gauge bystander responses to the use of drone AED delivery participants noted they found the system to be intuitive and helpful, they also expressed feelings of relief as the drone arrived providing supplies and guidance (Sanfridsson et al., 2019).

AED deliveries using UAS is only one example of many medical related supplies that can be delivered using UAVs. Another example of time sensitive medical delivery is the transportation of human organs marked for transplant. On April 19th, 2019, the first human organ, a kidney, was transported via drone to the University of Maryland Medical Centre and successfully used in the transplant surgery (Kettlewell, 2020). Other organ drone deliveries have continued, the first set of human lungs to be delivered by sUAS took place in September 2021 in Quebec, Canada (Forster, 2021).

Because of the early adopter mentality of the emergency response and medical industries towards UAS, these industries have shifted from studies to actual high-volume operations in some sectors. The company Zipline, established in 2014, is likely the most experienced UAS delivery company in the world. As of April 2021, the company had completed over 115,000 commercial deliveries including medications, medical supplies, personal protective equipment, blood, laboratory specimen, and vaccines. Zipline actively delivers 24 hours a day, seven days a week to over 25 million people across 3,000 hospitals or medical clinics. In response to COVID-19 the company delivered 4,500 vaccine doses on their first day of COVID vaccine delivery; they plan to distribute 2.5 million doses over the next twelve months (Munoz, 2021). Zipline uses a fixed-wing drone that weighs 46 pounds capable of flying up to 80 miles per hour, covering 100 miles round trip, and sustaining a payload of about 4 pounds ("Zipline", 2021).

Other use cases for sUAS not explored in this section include their use in real estate marketing, capturing special events, news coverage, cinema production, pollution and weather monitoring, drone entertainment shows, food and package delivery, recreational use, and educational use in primary and secondary schools. Big name package delivery companies like UPS, FedEx, Amazon are actively researching ways to use UAS as part of their logistics networks. On October 1st, 2019, UPS Flight Forward was the first all drone airline awarded a Part 135 operating certificate from the FAA. This UPS subsidiary company is actively building a revenue-generating package delivery UAS network within the existing federal regulatory framework (“U.S. Transportation Secretary Elaine L. Chao Announces FAA Certification of UPS Flight Forward as an Air Carrier”, 2019).

As demonstrated through the survey of a wide array of use cases across numerous industries, one can see the continual integration of sUAS. Usually with any disruptive technology there are challenges to be overcome to maximize the potential benefits. Although the uses of Unmanned Aircraft Systems have grown exponentially since the enabling 2016 Part 107 Regulation was passed, there remain several momentous obstacles to conquer. Questions around airspace integration, Unmanned Aircraft System Traffic Management (UTM), privacy/security concerns, general regulation, automation, safety, and more have yet to be fully answered as industries continue to find additional use cases for UAS. These obstacles and others will be further discussed in relationship to Advanced Air Mobility. The many uses of sUAS are a standalone category of AAM, but it is also serving as a testbed for technologies and a regulatory enabler to the use of larger unmanned aircraft for UAM and RAM use cases.

2.3 Large Unmanned Cargo Aircraft (LUCA)

Thus far the drone use cases presented have been largely surrounding existing UAVs weighing less than 55 pounds, which CFR 14 Part 107 defines as small unmanned aircraft (“Title 14 Code of Federal Regulations - Part 107”, 2016). Unmanned aircraft weighing 55 pounds or more currently have a different path to operation. Commercial operators seeking to utilize large UAS must pursue type certification for the aircraft or seek an exemption under 49 U.S.C. 44807, both of

which are lengthy processes (Malecha, 2019). Exploring alternative regulatory paths forward for Large UAS does not fall within the scope of this project, but within this section various Large Unmanned Cargo Aircraft (LUCA) and their potential uses will be explored.

LUCA is inclusive of aircraft capable of a couple hundred-pound payload all the way to autonomous 100-ton freighters (Ley & Organ, 2020). The Aerospace Industries Association of America (AIA) defined LUCA as a second stage adopter, predicting that between 2025 and 2031 there will be a significant increase in unmanned cargo aircraft operations opening the door for additional research and development investment into more autonomous operations. Cargo aircraft operating over sparsely populated areas or large bodies of water will likely be the first to reach fully autonomous status, which can help with the overall acceptance of the technology (“Think Bigger - Large Unmanned Systems and the Next Major Shift in Aviation”, 2018).

Companies are working on various concepts and designs for large cargo aircraft, some of which have made it to the testing phase. Elroy Air is a company that was founded in 2016 who set out to revolutionize same-day shipping and the overall cargo market (“Elroy Air”, 2022). Elroy Air has designed, built, and is testing an aircraft the company call the Chaparral. The Chaparral is a hybrid VTOL aircraft capable of a payload up to 500 pounds across a range of 300 miles using a hybrid-electric powertrain. The aircraft is one part in a comprehensive cargo logistics operating system as the Chaparral can autonomously land, drop a load, secure its next load, and return to the air for its next delivery (“About the Chaparral”, 2022). Elroy Air has secured orders for 500 of these aircraft equating to over \$1 billion in sales across commercial and military sectors (Sousa, 2022).



Figure 2: The Chaparral (Elroy Air, 2022)

Another example aircraft is the Rhaegal, from the Sabrewing Aircraft Company. The Rhaegal is a hybrid electric VTOL unmanned aircraft focused on the regional cargo market. At full scale it will be capable of carrying a payload of over 5,000 pounds over a distance of 1,000 miles with a cruising speed of over 200 knots (Sabrewing Aircraft, 2019). Sabrewing has focused on developing a highly innovative cargo aircraft, for example, the Rhaegal was designed to fly in inclement weather conditions, the entire surface of the aircraft has a heating system to deal with icing conditions. Prototypes of the aircraft have been built at smaller scale for the current testing program (Vertical Flight Society, 2022). The right-hand side of Figure 3 shows a depiction of the Rhaegal.

Natilus is another company also working towards unmanned cargo aircraft, but truly on the large scale. The company has goals to build remotely piloted aircraft capable of transporting up to 130 tons of cargo, see a depiction of the concept on the left-hand side of Figure 3. Natilus currently has smaller-scale prototype aircraft that are remote seaplane aircraft that can serve a payload of 700 pounds over 2500 miles. These are referred to as demonstrators of the technology that the company plans to scale up significantly (Ley & Organ, 2020).



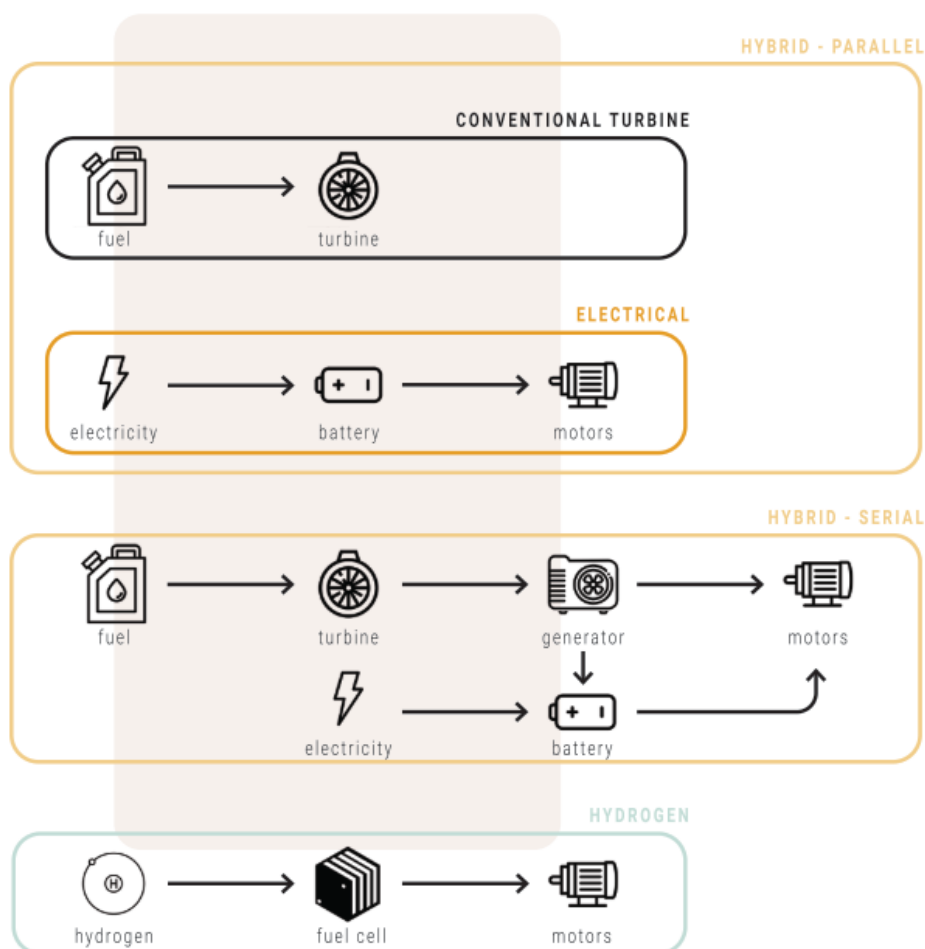
Figure 3: Natilus Next General Freightier (Natilus, 2020) and Sabrewing Rhaegal (Vertical Flight Society, 2022)

The LUCA sector is growing and has started to receive more research attention. An in-depth study considering five different aircraft designs and cargo configurations against various aerodynamic and performance criteria was conducted in 2017 (Hasan et al., 2018). A 2017 thesis by Rian van Groningen made the argument that unmanned cargo aircraft is a more sustainable and affordable option for cargo transportation over traditional aircraft, rail, shipping, and trucking (Van Groningen, 2017). A 2019 thesis by J. Wolters was focused on creating assessment tools and identifying markets and for unmanned cargo aircraft operations (Wolters, 2019). In 2020 an analysis of VTOL-capable large cargo drones for military applications and a review of current concepts from militaries across the world was published (Saastamoinen & Taipale, 2020). As various AAM technologies continue to advance, it is expected that the LUCA sector will continue to grow and perhaps serve as proof of concept for other RAM and UAM use-cases.

2.4 Electric and Hybrid Aviation

The technology emerging that enables existing aircraft to be retrofitted with hybrid or electric powerplants as well as the developments of aircraft with alternative power sources certainly falls under the Advanced Air Mobility umbrella. These developments can lead to a variety of benefits such as decreasing environmental detriments, lower operating costs, and new sustainable markets. Many companies are working to advance these alternative fuels and powertrains and continue to make progress through research, development and testing to overcome significant obstacles.

There are varying degrees of electrification goals across short range smaller aircraft all the way up to long-haul large airliners. According to Emmanouil in his work “Reliability in the era of electrification in aviation: A systems approach” the varying degrees of electrification are directly tied to the amount of electrical power providing thrust to the aircraft; hybrid propulsion systems would still include a gas engine or fuel cell and all electric designs rely on electrical energy storage (2020). Below in Figure 4 and Figure 5 there is an overview depiction of various propulsion systems.



▲ Figure 9. Schematic overview of different energy systems in aircrafts (McKinsey Seminar, 2020).

Figure 4: Propulsion Systems Overview (Verboog, 2021)

Four Cardinal Electric Propulsion Architectures

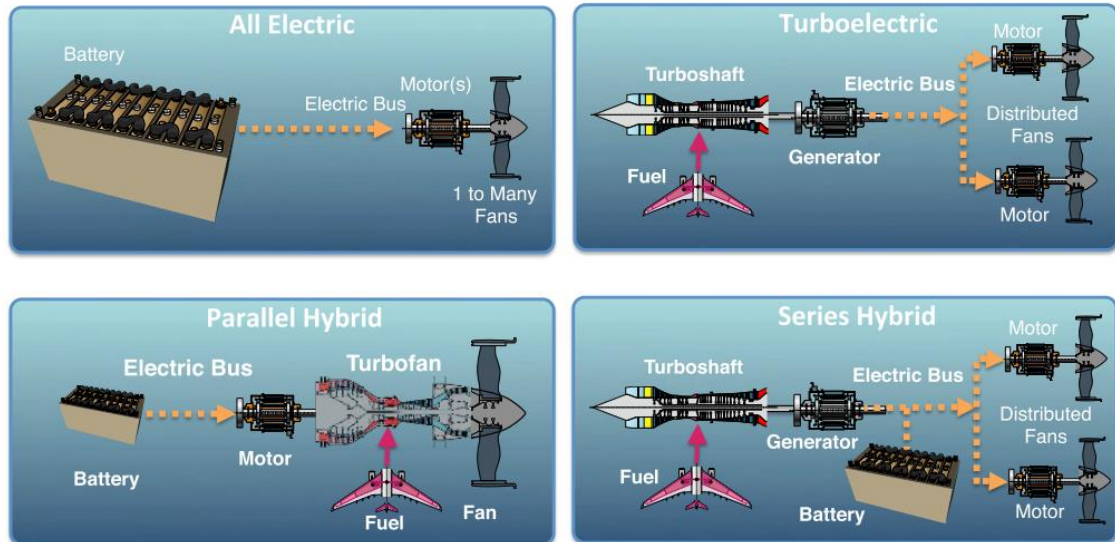


Figure 5: Overview of Propulsion Systems (Madavan, 2016)

A review of some of the leading aircraft and electric propulsion systems reveals the reality of the progress and trajectory of electric aviation. See Table 1 below, it is important to note this is just a small sampling of the many companies progressing with electric, hybrid or hydrogen powered aircraft designs.

Table 1: Overview of aircraft with electric or hydrogen propulsion systems (Author)

Company/Aircraft	Propulsion System	Number of Pax	Anticipated Range	Anticipated Speed	Anticipated Service Entrance	Source
Joby Aviation S4 	All Electric	4	150+ miles	200 MPH	2024	Joby Aviation, 2022
Archer Aviation 	All Electric	4	60 miles	150 MPH	2024	Archer, 2022
Harbour Air E-Beaver 	All Electric	6	100 miles	Unknown	2023	Harbour Air, 2021
Eviation Alice 	All Electric	9	500+ miles	250 KTS	2024	Eviation, 2022

ZeroAvia 	Hydrogen	6	250 miles	Unknown	2023	ZeroAvia, 2020
Heart Aerospace ES-19 	All Electric	19	250 miles	180 KTS	2026	Heart Aerospace, 2022
Wright Electric 	All Electric	100	450 miles	Unknown	2026	Wright Electric, 2022
Airbus 	Hydrogen	100-200	1,000-2,000	Unknown	2035	Airbus, 2022

While the ultimate goal is emissions free aviation across the board, this current time period serves as an intermediate time for additional research and technology advancements to scale the technology to larger aircraft. A few of the aircraft in Table 1 are existing certificated airframes that have been retrofitted with different propulsion systems. The Harbour Air E-Beaver is the union of the old and the new as the DeHavilland Beaver aircraft was released in 1947 and produced for 20 years (Marsh & Baker, 2006). The E-Beaver is powered by a 750 horsepower MagniX electric propulsion unit (EPU) coupled with an H55 battery pack. Because no changes have been made to the certificated airframe, certification of the electric powerplant and battery system is sought through a supplemental type certificate (STC) program (Harbour Air Seaplanes, 2021). The timeframe for this type of certification using already proven aircraft is much shorter, ranging from three to five years versus the five-to-nine-year process for new aircraft certification (Federal Aviation Administration, 2019).

The MagniX EPU technology was not only used in the E-Beaver but was also successfully placed in a Cessna Grand Caravan 208B becoming the world's biggest all-electric commercially focused aircraft in the summer of 2020 ("Modified Cessna Is the Largest Electric Aircraft to Take Flight", 2020). MagniX was also selected as the electric powerplant provider for the 9-seat Eviation aircraft seeking certification by 2024 ("Our Journey", 2020). In September 2021 MagniX was recognized for their accomplishments thus far and were awarded over \$74 million by NASA to enable their continued research on providing reliable electric propulsion systems (NASA, 2021).

Two other aircraft from Table 1 are existing airframes being coupled with emerging technology. The BAe 146 is a 4-engine short-haul airliner that originally entered service in 1983, it was produced by the British Aerospace company (Birtles, 2016). The Wright company plans to use the BAe 146 with all four engines eventually being all electric propulsion and seeks to introduce the electric version of this well-known regional aircraft into service by 2026 (Wright Electric, 2022). The last existing airframe is the ZeroAvia Piper Malibu which became the first all hydrogen powered aircraft in the summer of 2020 (ZeroAvia, 2020). This

aircraft was used as a test bed within the greater research and development goals of ZeroAvia to scale up hydrogen propulsion to larger aircraft capable of carrying 20 to 100 passengers (ZeroAvia, 2022).

Retrofitting existing airframes of long proven aircraft with these new propulsion systems bridge the gap to new all electric aircraft. Aircraft such as the eVTOLs from Joby and Archer and the new Conventional Take-off and Landing (CTOL) aircraft such as the Eviation Alice and Heart Aerospace ES-19 designs. In the case of the ZeroAvia Piper hydrogen program it also lays a strong foundation for additional research across the industry, which can lead to the next generation of aircraft as Airbus envisions. Airbus is considering three different aircraft designs as they work towards hydrogen powered aircraft capable of carrying 100-200 passengers over on long haul flights of up to 2,000 miles (Airbus, 2022b). In February 2022 as part of the Airbus ZEROe program it was announced that original A380, named the MSN1 will serve as the flight laboratory for new hydrogen technologies. Airbus noted the size of the A380 is ideal for the large hydrogen tanks, fuel distribution system, and monitoring systems as these new technologies are tested and mature. (Airbus, 2022a).

Hydrocarbon fuel has been the power source of choice for aviation for so long because of the high energy density of 11,900 Wh/kg (Swanson et al., 2021). While the hydrocarbon fuels provide high energy it comes at a high financial and environmental cost. Fuel is one of the highest costs airlines face second only to the labour costs ("Passenger Airlines Operating Costs, United States", 2019). Harmful CO₂ emissions from aviation make up nearly three percent of total energy-use-related CO₂ emissions. Estimations also note that non-CO₂ warming impacts from aircraft are also near three percent, thus doubling the aviation industry climate change contribution (Schäfer et al., 2018). These aviation emissions are not only harmful to the overall environment, but studies show they lead to about 16,000 premature deaths (Yim et al., 2015). Studies also show the increasing number of negative health impacts that aircraft noise can produce, such as increased risk of heart attack, hypertension and strokes. (Wolfe et al.,

2017) These negative outcomes and the high costs of traditional aviation fuels are some of the top driving forces of the electric aviation revolution.

Electric aircraft can completely eliminate the direct combustion emissions of traditional propulsion systems (Schäfer et al., 2018). Although electric propulsion can be a big step in the right direction, the electric energy stored comes from some means of generation and is only as clean as its source of production (“Washington Electric Aircraft Feasibility Study”, 2020). Traditional aviation is known to be extremely loud, companies designing the next generation of hybrid and all-electric aircraft are invested in delivering on the promise to greatly reduce noise pollution. This reduction in noise pollution can greatly benefit individuals’ health by lowering their higher risks to heart attacks and other serious health concerns, especially those residing near airports or future vertiports (Riboldi et al., 2020).

Another big benefit of electric aviation is the lower operating costs, one of the first places this can have a big impact is on pilot training. The Pipistrel Velis Electro is a two-seater light sport or training aircraft that is the first all-electric powered airplane to receive a type certificate by the European Union Aviation Safety Agency (Pipistrel USA, 2021). This aircraft has a range of roughly 100 miles on one charge with an hourly operating cost of about \$25. With the current hourly operating cost of \$150-200 for the famous Cessna Skyhawk 172 training aircraft it is expected that flight schools would adopt electric aircraft as more of them become certified (Thapa et al., 2021). In their study “Flight School Perceptions of Electric Planes for Training”, Edwards and Parker found that the majority of student pilots, Certified Flight Instructors (CFI) and flight school owners are receptive to electric aircraft (2022). See Figures 6 and 7 below from their work that graph the results from two of the survey questions that were asked across hundreds of participants.

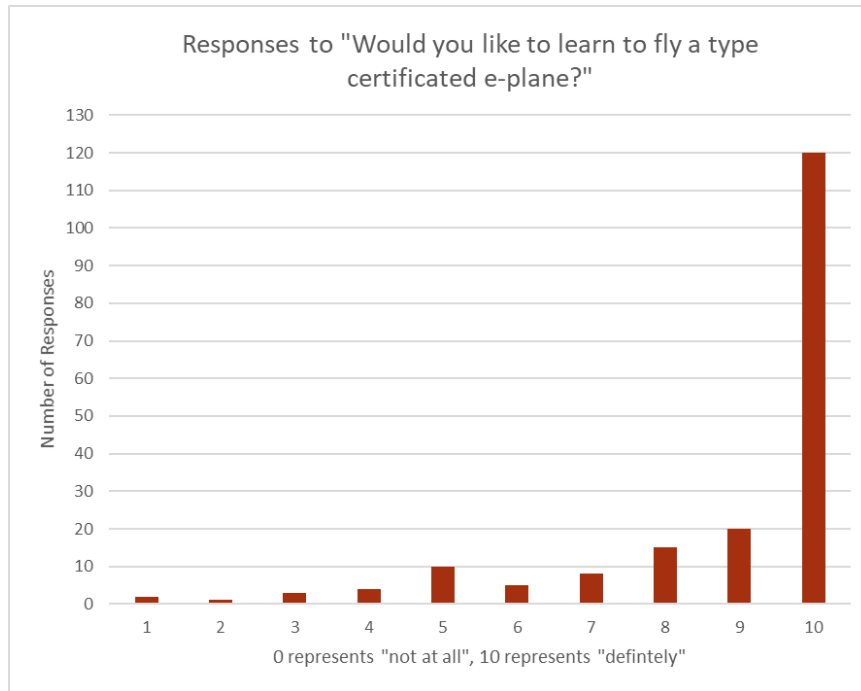


Figure 6: Survey Results - Electric Training Aircraft (Edwards & Parker, 2022)

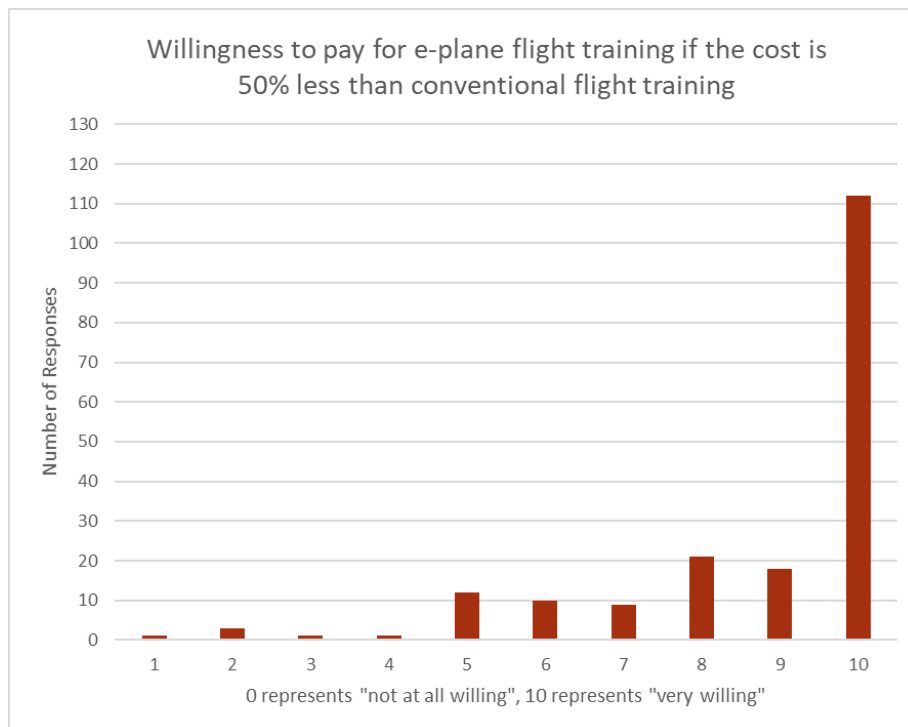


Figure 7: Survey Results - Electric Training Aircraft (Edwards & Parker, 2022)

The cheaper hourly operating costs experienced by training aircraft is also a benefit that will be experienced by commercial operations aircraft, sampled in Table 1. An advantage of electric propulsion systems is their ability to convert about 90% of stored energy into kinetic energy, only losing 10% to heat and noise. This allows these various eVTOL and eCTOL aircraft to be viable on routes up to about 1,000 miles (Swanson et al., 2021). Due to the comparatively low number of moving parts in the more simplistic electric motors another potential operational savings will come from the lower amount of expected maintenance (Schäfer et al., 2018). These lower operating costs open the door for new routes on a regional basis, this will be discussed in the Regional Air Mobility section.

Despite the many benefits and advancements of electric aviation there are still significant obstacles to overcome. Some of the key propulsion challenges are the weight of the batteries, heat created by the superconducting electric motors, and meeting the established safety and reliability standards required for certification (Madavan, 2016). Although battery technology is improving, there are still concerns about the battery capacity and charging time and how these relate to range and route demand (“Washington Electric Aircraft Feasibility Study”, 2020). Although these obstacles exist, the aviation industry is on a solid trajectory towards more mature electric or hydrogen propulsion technology that will enable the goals of a more environmentally safe and sustainable aviation system.

2.5 Rural Air Mobility (RAM)

Rural or Regional Air Mobility falls under the AAM umbrella term and is the use of eVTOL and eCTOL aircraft in a regional point-to-point model, connecting various urban centres and/or regions. The new electric aircraft anticipated to enter service over the next decade will enable a viable shift to open a more point-to-point market. It is expected that these new routes will provide economic benefits and sustainable growth across all aviation markets (Swanson et al., 2021). The advancement of these electric aircraft will lead to job growth in regions that adopt these technologies. Growth in work sectors related to the operation and maintenance of the aircraft, the planning, engineering, and building of the infrastructure (“Washington Electric Aircraft Feasibility Study”, 2020).

The benefits of more regional connectivity are anticipated to be similar to what is being seen with the adoption of sUAS. Benefits around better health care, increased emergency response capabilities, additional industry use-cases, and a more robust transportation system. The opportunity for eVTOL and eCTOL air transportation is not meant to replace other modes of transportation such as highways and high-speed rail, rather the emergence of RAM is anticipated to integrate with these other modes of transportation, leading to a more sustainable transportation ecosystem (Swanson et al., 2021).

2.6 Urban Air Mobility (UAM)

The term Urban Air Mobility is a relatively new term in the world of transportation and more specifically in the aerospace and automobile industries. Because the term and overall concept is so recent it is actively evolving and is defined differently by the varying companies and stake holders occupying the novel space. For the purposes of this research UAM is defined as: on-demand or scheduled air service to transport passengers or cargo using piloted or autonomous electric vertical take-off and landing (eVTOL) vehicles. Although some examples were shown in Table 1, Figure 10 provides additional visual representation of various vehicle concepts currently in different stages of testing and certification.



Figure 8: Examples of eVTOL aircraft (Joby, 2022, Volocopter, 2022, Lilium, 2022)

There has been rapid growth and investment into the research and development of these eVTOL aircraft. According to the Vertical Flight Society in January of 2018 there were 50 different eVTOL vehicles in development, by July 2018 the 100th one was recorded, in January 2019 the number climbed to 150 and by September of 2019 there were over 200 unique eVTOL aircraft in development (Vertical Flight Society, 2019). The label of Urban Air Mobility is perhaps too

limited because it implies these innovative aircraft will only be used for intracity travel. But the 200 eVTOL aircraft in development are being designed for an assortment of missions ranging from intracity travel, intercity or rural mobility, cargo and package delivery, emergency medical transport, search and rescue operations and other purposes yet to be discovered.

These diverse missioned eVTOL aircraft can take off and land vertically like a helicopter, the landing facilities that will be used have names such as skyports or vertiports. Because helicopters were invented over 80 years ago the ground infrastructure terms of helipad and vertiport are not new terms. The United States Federal Aviation Administration (FAA) defines vertiports as an identifiable ground or elevated area, including any buildings or facilities thereon, used for the take-off and landing of tiltrotor aircraft and rotorcraft. An additional term used is a vertistop which is intended solely for take-off and landing of tiltrotor aircraft and rotorcraft to drop off or pick up passengers or cargo (Federal Aviation Administration, 1991). As related to the UAM industry, the terms skyports and vertiports are often used interchangeably in reference to multiple landing pads and operation facilities to support eVTOL aircraft. Figure 9 illustrates futuristic concepts of eVTOL purposed vertiports.

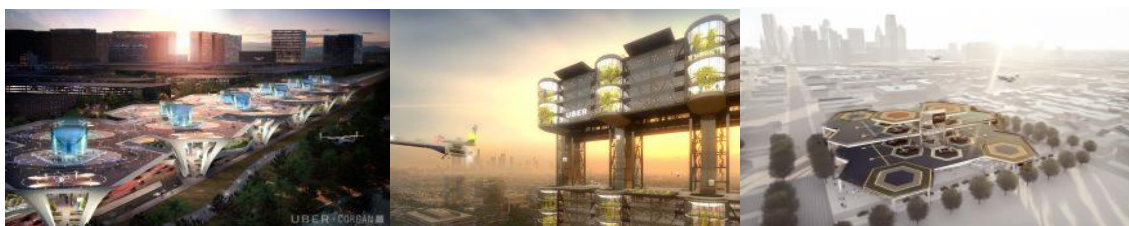


Figure 9: Examples of future designs of vertiports (Kellen, 2018)

2.6.1 Flying Car History

Although Urban Air Mobility and Advanced Air Mobility are the latest terms used to describe the concept of urban air transportation, it not a new idea. There has been a variety of terms used over the years. In his thesis, “Systems-Level Analysis of On Demand Mobility for Aviation”, Parker Vascik created a table outlining the history of terminology of using aviation transportation within cities, this table is included below as Figure 10.

Term	Usage Dates
Helicopter Air Carrier	1953-1976
Air Taxi	1962-2016
Metrotaxi/Metrobus	1970
Intracity Air Transportation	1970
Interurban Short Haul Air Transportation	1973
Personal Air Transportation	2006
On Demand Aviation	2010-2015
On Demand Air Mobility	2012
Zip Aviation	2012-2014
Sky Transit	2015-2016
On Demand Mobility	2015-2016
Air Mobility on Demand	2016
On Demand Urban Air Transportation	2016
Urban Air Mobility	2016

Figure 10: Urban Air Transportation Terminology History (Vascik, 2016)

At the core of Urban Air Mobility is the idea of using aircraft as a form of transportation in non-traditional markets, for example, intracity travel. As demonstrated by the various terms over the years this idea is not a new concept, the idea appears virtually at the beginning of automobiles and airplanes becoming a reality. The idea evolves and takes on various forms throughout the last century as innovators sought to combine emerging technologies of their day and enable new modes of mobility or to use existing modes in a novel way.

At the same time the automobile was coming on scene in the late 1800s, many determined inventors continued to experiment with gliders and various power plants seeking to accomplish sustainable, controlled flight. It was in the same year of 1903 that the automobile and the airplane would both find success and quickly grow from humble beginnings. Henry Ford, the mastermind behind the Model T automobile, started the Ford Motor Company in the summer of 1903 and went on to produce over 15 million Model T cars (Crowther & Ford, 2015). The Wright Brothers achieved the quest for heavier-than-air sustained and controlled flight on December 17th, 1903, and the modern-day aircraft was born (Montgomery, et al., 2013).

As automobiles and airplanes grew from their infancy inventors looked for ways to combine the utility of these two new forms of transportation. By February of 1919 the aviation pioneer Glenn Curtiss received a patent for the first flying car known as the Curtiss Autoplane (Schreiner, 2018). This autoplane had a fuselage that resembled an enclosed car which then had three wings, a pusher propeller and tail section, it can be seen in Figure 11. In 1923, only twenty years after the Wright Brothers first flight, the idea of a flying car took on yet another pioneering technology: vertical take-off and lift. The 1923 Pitcairn PCA-2 looked like a typical monoplane of the day, but also contained a set of rotary wings for vertical lift using auto-giro technology. In 1935 the Autogiro Company of America was permitted to land an AC-35 giro-aircraft on the lawn of the White House and then drive as a “roadable aircraft” to the Bureau of Air Commerce building (Schreiner, 2018). A photograph of the event can be seen in Figure 11.

Fast forward to the 1950s which is when two flying cars were certified in the United States. The first was the Foulton Airphibian which was certified by the Civil Aviation Administration in 1950 (Smithsonian National Air and Space Museum, 2020). The second was the Taylor Aerocar which was later certified by the Federal Aviation Agency and is depicted in flight in Figure 11. In the 1970s the Ford Motor Company explored marketing and producing the Aerocar (Rajashekara et al., 2016). Both the Airphibian and the Aerocar had similar designs which allowed the car portion to be disconnected from the empennage and wings of the aircraft portion, thus allowing it to then drive on the road. It could then be reconnected and transform back into a flying aircraft. The conversion from car to airplane or airplane to car could be done in about five minutes with the Taylor Aerocar (Rajashekara et al., 2016). The companies behind these flying car creations were never able to get the necessary traction to mass produce and sell these flying/driving machines.



Figure 11: Curtiss Autoplane (San Diego Air & Space Museum, 2020), AC-35 Roadable Aircraft (Watkins, 2009), Taylor Aerocar (Hill, 2010)

2.6.2 Helicopter History

The traditional fixed-wing aircraft creates lift by pulling the wing through the air thus producing upward lift. Rotary-wing aircraft use large rotors or propellers on top of the aircraft that operate as wings, as the rotors spin through the air it creates vertical lift. Experimenters had been working to create a helicopter using the rotary lift method as early as the 1840s when a man by the name of W.H. Phillips flew his model helicopter that had steam jets serving as the power plant (Montgomery, et al., 2013). It was a few short years after the Wright Brothers' successful flight that another bicycle maker made his mark on history. Paul Cornu built and "flew" the first helicopter in 1907, this crude aircraft was not very controllable but did carry Cornu off the ground using vertical lift by rotary-blade (Montgomery, et al., 2013). The issue of control for helicopters would prove to be the main problem to be overcome and it would take decades before a viable helicopter would come onto the scene.

In the 1920s gentlemen by the names of Georges de Bothezat and Ivan Jerome designed and built the largest helicopter of the day for the United States Army. This large flying machine was known as the "Flying Octopus" and used a quadrotor design; the issue of control was remedied by coordinated blade pitch. Although this helicopter had many successful flights the aircraft was slow, difficult to control and not financially feasible, this resulted in a cancellation of the contract, and it would be another fifteen years before a pure helicopter flew again in the United States (Leishman, 2013).

Igor Sikorsky is a well-known figure in aviation history who made multiple contributions to the advancement of both fixed-wing aircraft and helicopters.

Sikorsky was a pioneer of combining two modes of transportation when in 1913 he successfully built and piloted a large four-engine flying boat (Montgomery, et al., 2013). As he gained success with various fixed-wing aircraft designs he also experimented with vertical lift. In 1935, Sikorsky received a patent and by 1940 had built and was flying the first modern-looking helicopter which was known as the VS-300. Within three years he had been through three different models, each with more capabilities, and by 1943 a few hundred of Sikorsky's R-5 Helicopter were used in the Pacific Theatre of World War II (Leishman, 2013). Sikorsky's success lives on today through his company: Sikorsky Aircraft Company.

In the same time era, another company that also still exists today was making a big breakthrough with rotary-wing aircraft. Lawrence Bell, founder of Bell Aircraft Corporation, hired an inventor named Arthur Young and together they built the Bell-30 Helicopter in 1942. This design quickly proved itself at speeds greater than 70 miles per hour. After noting several improvements that could be made, they built and released the Bell-47 Helicopter which became the first helicopter to be commercially certified; over 6,000 Bell Model 47s were produced (Leishman, 2013).

In the 1940's the modern helicopter was born and over the next two decades the vertical flight industry exploded with advancements. Various models of helicopters began to be widely used within militaries around the world and across a wide array of commercial use. History demonstrates again and again the natural attraction inventors have to combining different transportation technologies. This again proved to be true with fixed-wing airplanes and rotary-wing helicopters. Teams of engineers at aircraft manufacturing companies were on a quest to create a machine that could combine the benefits of vertical take-off and landing from a helicopter with the benefits of high-speed efficient cruise from a traditional airplane. In the 1950s is when ideas of tilt-wing aircraft and tilt-rotor aircraft began to surface (Leishman, 2013). The concept of a tilt-wing aircraft is to allow the wings to tilt from a traditional multi-engine, fixed-wing position back to where the propellers are then in a position to enable vertical take-off. A tilt-rotor aircraft is a

very similar concept where only the rotors tilt back and forth on the tips of the wings rather than the entire wing.

By 1957 the Boeing-Vertol company had produced and began test flights of the VZ-2 tilt-wing aircraft. This aircraft was one of the first successful tilt-wing designs that went on to perform many successful flights and conversions from a helicopter position to an airplane position. The VZ-2 was flown until 1965 but due to the design resulting in piloting difficulties that could not be overcome, the project was laid to rest (Dugan, 2014). Other tilt-wing aircraft prototypes were built and tested by various companies, but the tilt-rotor design began to quickly earn more attention. The Bell Aircraft Corporation in connection with the Transcendental Aircraft Corporation were the first to demonstrate a tilt-rotor design in 1954 (Leishman, 2013).

Bell would go on to develop multiple tilt-rotor designs over the next fifteen years that lead them down the path to the creation of the XV-15 which was first flown in 1977 (Gertler, 2011). By 1983 Bell and Boeing teamed up to take the XV-15 to the next level and the V-22 Osprey program was born. The V-22 Osprey is a tilt-rotor aircraft capable of the VTOL operations of a helicopter and the top cruise speed of 350 MPH in traditional fixed wing configuration. After twenty years of development and improvements this aircraft is used by various military branches in forces around the world (Whittle, 2011).



1922 Flying Octopus

Bell-47

V-22 Osprey

Figure 12: The evolution of helicopters and eventual VTOL aircraft (De Bothezat, 2007, Fantasy of Flight, 2022, Szondy, 2019)

2.6.3 Helicopter Airlines

The idea of people using aviation as a form of everyday transportation is not a concept of present day. As aviation technology continued to advance, this idea of urban air travel could be seen by the public in entertainment. The animated

cartoon show “The Jetsons” aired in September 1962 and told the story of a family living in a highly advanced world. The show depicted the citizens of Orbit City using flying cars to travel to work, to school or to the local grocery store (Novak, 2012). Today in the industry of UAM the term “Jetsons Era” is commonly used when describing the future because of this iconic cartoon.

Throughout the 1960s, the use of flying vehicles to avoid ground traffic within cities was not just an idea of television shows, but a true business venture of countless companies who made it a reality with helicopters. The start of helicopter-based transportation companies was nearly identical to the start of early day airlines, both started by first carrying air mail. In 1947 the Civil Aeronautics Board (CAB) created an air carrier classification titled Helicopter Airmail Lines; the Los Angeles Airways company was the first to take advantage of this new classification (Dajani et al., 1976). This air carrier classification was later expanded to include carrying cargo and passengers thus creating an opportunity for companies to start scheduled and on-demand helicopter services.

Companies throughout the United States entered this new short-haul, intercity and intracity transportation market. New York Airways was one of the first airlines to use both helicopters and Short Take-off and Landing (STOL) aircraft on various routes within the greater New York City and New Jersey area. They grew from carrying 5,000 passengers in 1955 to 342,000 in 1974. New York Airways most popular route was from the Pan Am Building in the Central Business District (CBD) of Manhattan to the John F. Kennedy International Airport (Dajani et al., 1976). In their peak years Los Angeles Airways provided service to over 400,000 passengers on routes between various locations and the Los Angeles International airport. SFO Helicopter Airlines and Chicago Helicopter Airways were other prominent examples of successful scheduled urban air transportation companies. In addition to these scheduled helicopter airlines, in 1975, there were over 100 companies registered as air taxis operators utilizing only helicopters for non-scheduled, on-demand air transportation (Dajani et al., 1976). The increase in these urban air operations resulted in an increase of landing infrastructure in the means of heliports. The number of heliports in the United States increased

from 346 in 1960 to over 4,000 by 1984 (Aerospace Industries Association of America, Inc, 1984).

The growth that took place in this new market prompted researchers from various government agencies, academic institutions, and private industry to conduct studies in an effort to better integrate air transportation into the urban environment. In 1967, the Lockheed-California Company published a report called "Vertiport Design and Operations" where studies of the day predicted a growth of intercity air transportation and use of vertiports (Cheyno, 1967). In 1969, professors from the Massachusetts Institute of Technology (M.I.T.) conducted simulations studies for the use of Vertical Take-off and Landing (VTOL) vehicles within heavily populated cities (Taneja & Simpson, 1969). In 1970 another M.I.T. research report entitled, "Ground Facilities for a VTOL Intercity Air Transportation System", was published. This report discussed a systematic approach to short haul air travel within metropolitan areas. The report made many recommendations on topics such as regulation, airspace, funding, and the ground infrastructure of the system. The larger focus of the research was a focus on the location, planning, design, and operation of ground facilities in support of what was being called the "airbus system". These ground facilities at the time were called metroports (Allen & Simpson, 1970).

These ideas of integrating urban air travel into the existing city transportation system continued throughout the 1970's. The National Aeronautics and Space Administration (NASA) led these efforts in many regards and commissioned several studies focused on establishing a system where intercity air transportation could be expanded and used by the general public. The idea was to take this new service being used by wealthy individuals and businesses and develop it into a more public service. However, on May 16, 1977, a tragic helicopter accident on top of the Pan Am building in New York City took the lives of five people (McFadden, 1977). As a result of this high-profile accident and continued community backlash against noise within major cities across the United States the concept of the general public using helicopters for city air travel never

took off. Many of the legacy helicopter airlines went out of business and others adapted to offer private charter services only in the viable markets.

By the late-1980s as the development of the V-22 Osprey and other similar technologies continued to progress, the attention of NASA and the Federal Aviation Administration (FAA) once again began to focus on the possibility of city air transportation. Figure 13 shows the timeline of different NASA sponsored development projects of VTOL technology from 1987 to 2011. In May of 1991 the FAA published Advisory Circular 150/5390-3 on Vertiport Design. In the Advisory Circular (AC) introduction it referenced the ideal of using “tiltrotor technology to offer a viable city-centre to city-centre air transportation system”. It referenced the potential air transport capacity enhancement and potential paybacks of using such a system. The AC referred to a study done within New York City where at least a 20 percent capacity gain was possible, the language of the publication encouraged city planners and air transportation experts to work together in establishing intercity air transportation systems within their cities. Unfortunately, many of these efforts never made it past the research and development phase and realizing this ideal of such a system was essentially abandoned for various reasons leading the FAA to eventually cancel this Vertiport Design AC.

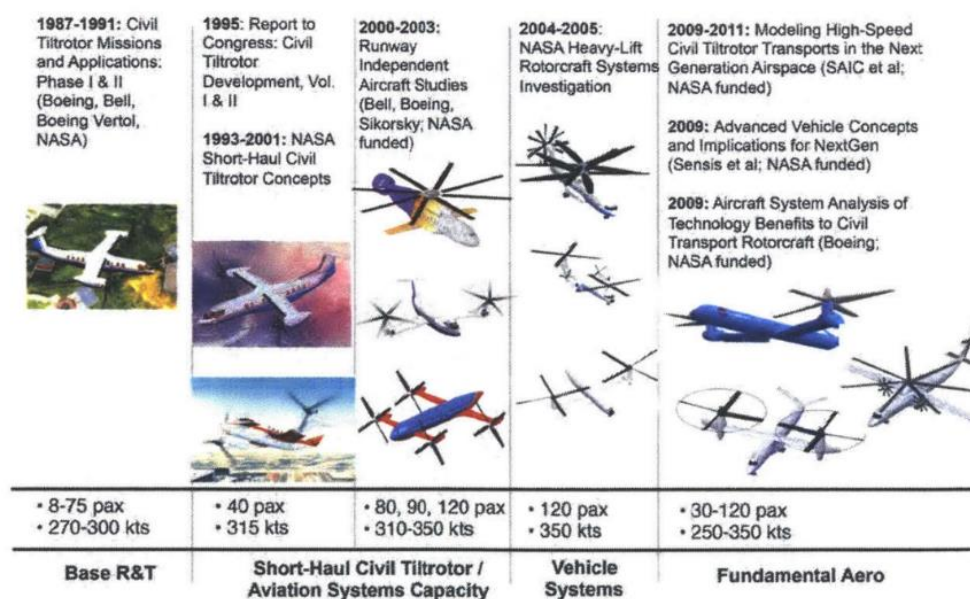


Figure 13: Timeline of NASA sponsored developments (Colucci, 2016)

2.6.4 Urban Air Transportation Revived

Although government agencies seemed to turn away from the idea for a time, private industry continued to explore how one day urban air travel could become a reality. In a world of increasing ground traffic and ever advancing technology one can see how the idea of using VTOL aircraft in large urban areas has once again been revived. In 2016 the rideshare company Uber started a subsidiary company called Uber Elevate with the mission to take a leading role in paving the way for the future of UAM. In October 2016 Uber Elevate released a white paper entitled “Fast Forwarding to a Future of On-Demand Urban Air Transportation”. This white paper served as a catalyst within the industry and once again started the larger discussions between industry, academia, and regulatory agencies regarding UAM.

In 2016 The Vertical Flight Society started the eVTOL Aircraft Directory where the intention was to track the progress of the known concepts of eVTOL aircraft in various stages of research, development, design, testing and eventually certification. When this directory was started in 2016 there were only six known aircraft designs, by the start of 2021 the directory contained over 300 eVTOL aircraft organized into the following categories: vectored thrust, lift/cruise, wingless multicopter, electric rotorcraft, and personal flying devices (Vertical Flight Society, 2021) Similar to the space race there is a race amongst the various aircraft manufacturers and start-up companies on who will be the first to earn FAA certification thus making them first to market.

In 2018 Uber Elevate hosted a skyport design competition where many architect and planning firms participated and published a wide variety of skyport design concepts. Although many of these designs were futuristic in nature it brought attention to the physical infrastructure that is needed to support these eVTOL aircraft as they come to market. Also, in the year of 2018 NASA published an Urban Air Mobility Market Study that researched different use cases and predicted their financial viability by 2030. The study identified various obstacles to be overcome and dependencies on the market in order to reach viability. This NASA market study used over 100 assumptions which is why in the conclusion a

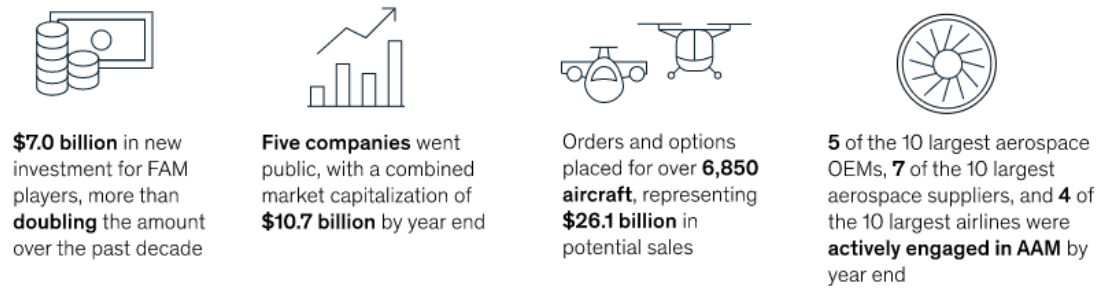
clear call to action was made asking for the industry to collaborate with researchers and create more congruent efforts to advance UAM (“Urban Air Mobility Market Study”, 2018).

Just as NASA has historically done concerning city air travel, the organization once again has taken a leading role. In the Spring of 2020 NASA kicked off the Advanced Air Mobility Ecosystem Working Groups. These working groups are dedicated to creating opportunities to collaborate across industry and regulatory organizations, forging strategic partnerships, and developing a path forward for AAM technology, systems, operations, regulation, and public acceptance (“Advanced Air Mobility Mission”, 2020). In the inaugural meeting of these NASA AAM Ecosystem Working Groups NASA presented the organization’s aggressive timeline where the goal is to realize scaled demonstrations of automated and complex operations at high-volume vertiports by the year 2025 (Hackenberg, 2020).

Also, in the Spring of 2020 the SARS-CoV-2 or coronavirus began to wreak havoc throughout the world. It was the start of one of the deadliest global pandemics in world history. To limit the spread of this highly contagious and deadly virus governments around the world issued travel bans. As a direct result of these travel bans and public’s concern for health safety the world airlines saw a 90 percent reduction in passenger demand (Heffintrayer et al., 2020). Throughout the year 2020 various sectors of the travel, transportation, and hospitality industries continued to be among the hardest hit. Many sectors of the aviation industry were negatively impacted by COVID-19, but AAM has continued to progress largely undisturbed (Dietrich et al., 2020).

Despite the pandemic and how difficult the global situation continued to be, there were several eVTOL aircraft manufacturers that made tremendous progress and key things that took place across the AAM industry in 2021. Below is Figure 14 which outlines the AAM 2021 progress, this figure is an image from the McKinsey & Company report: “A milestone year for future air mobility which demonstrates some of the key progress” (Esqué & Riedel, 2022).

2021 was a record year for future air mobility.



McKinsey
& Company

Figure 14: AAM Progress in 2021 (Esqué & Riedel, 2022)

Progress in power electronics, data links, sensors, communications, electric propulsion, battery storage, and technology in general has continued to create this excitement around leveraging these advancements to solve some growing problems. It is bringing people together from the aviation, automotive, technology, start-ups, ground transport, and other industries all into the continuous growing industry of AAM (Straubinger et al., 2020). The increased adoption of sUAS, the advancement of unmanned large cargo aircraft, the continued technological gains for alternative propulsion systems, the progress of many companies and aircraft, and growing investment into the industry has opened new doors into urban and regional air transportation. Perhaps these new enabling technologies will accomplish what has been tried for so much of aviation history.

2.6.5 Obstacles to AAM

There are a variety of obstacles to be overcome before AAM can be a realistic transportation option in cities across the world. NASA has categorized these obstacles into five high-level pillars that can be seen in the figure below.

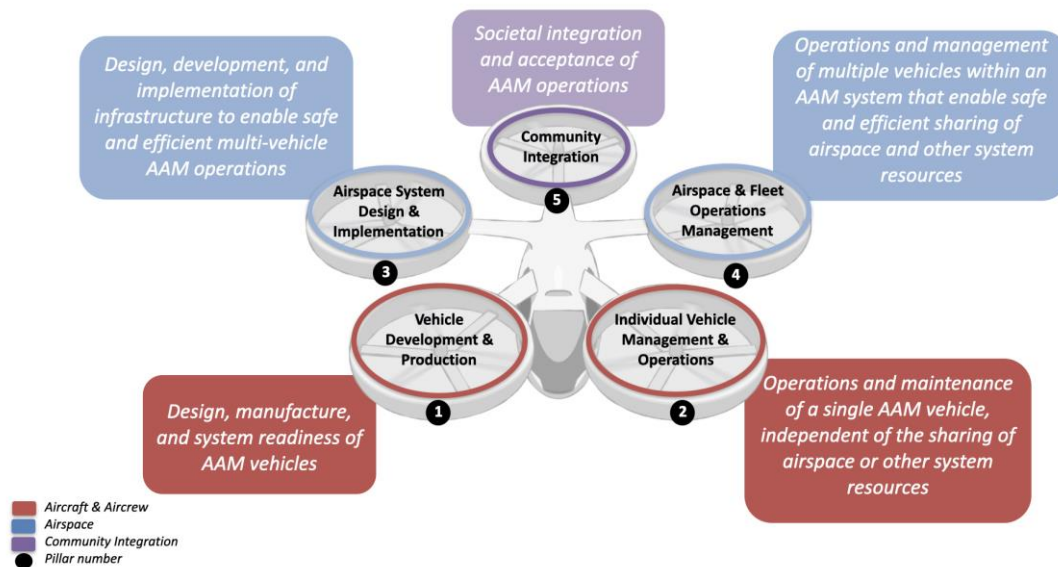


Figure 15: NASA Five Pillars of AAM Obstacles (NASA, 2020)

2.6.5.1 Market Demand

For any product or service to be successful there must be customer demand. One of the important questions around AAM is will there be a viable market for these services? There is a variety of literature that has explored this question. In 2018 with contributions from Crown Consulting, Ascension Global, Georgia Tech, and McKinsey & Company a pioneering Urban Air Mobility Market Study was released by NASA. This study forecasted demand across three different AAM use cases: last mile package delivery, air metro, which was considered scheduled public transportation, and on-demand air taxi. The study was informed by a survey of over 2,500 participants across five major US cities and from over 100 Subject Matter Expert interviews. The study concluded that last mile package delivery and air metro use cases could be profitable by 2030, while air taxi uses would be overall limited by 2030 (“Urban Air Mobility Market Study”, 2018).

In the same year, the consulting firm Booz-Allen-Hamilton presented to NASA their own Urban Air Mobility Market Study. This study aimed to provide a thorough analysis and market viability in ten top cities for three AAM use cases, which included airport shuttle, air taxi, and air ambulance all using eVTOL or hybrid VTOL aircraft. The study determined that the airport shuttle and air taxi markets

were viable, while due to technology constraints the air ambulance market was not viable (Booz Allen Hamilton, 2018).

Another company that has done significant work in identifying potential markets is NEXA Advisors. In 2019 NEXA announced the availability of a study that examined the barriers, first use cases, and investment resulting in a demand and economic forecast across over 70 cities around the world (NEXA Advisors, 2019). High level results from this study show that “despite the many differences, even the smallest cities will eventually create sustainable and profitable UAM services for their communities.” (UAM Geomatics, 2019). NEXA has also published highly detailed market studies for Vancouver, British Columbia, Toronto, and the state of Ohio (NEXA Advisors, 2021).

There are other research efforts seeking to answer the question around AAM demand. Balac et al. found that higher utilization of automation and technology will enable lower prices for AAM, thus positively impacting demand (2019). Kloss and Riedel explored consumers’ willingness to adopt AAM technologies in their article “Up in the air: How do consumers view advanced air mobility?” (2021). Rimjha et al. completed a feasibility study and estimated what AAM demand may be like in the Northern California region (2021). This is only a sampling of the many AAM market demand studies that have been completed in an effort to identify the business viability of AAM services.

2.6.5.2 Aircraft Design and Certification

The design, certification, and eventual production of AAM aircraft has received a lot of attention from regulatory bodies, Original Equipment Manufacturers (OEMs), investors, and researchers. As established in Section 2.6 Urban Air Mobility and Section 2.6.4 Urban Air Transportation Revived there has been an exponential increase in the amount of AAM aircraft in different stages of development and significant increases in investment across the industry, mainly towards getting leading aircraft through the remainder of the certification process.

In 2017, Kenneth Swartz performed an analysis and overview of many of the popular eVTOL aircraft of the time (2017). In June 2018 Uber Elevate released

eVTOL Vehicle Requirements for what they had envisioned for UAM and AAM missions. These requirements included VTOL capabilities, safety standards, noise levels, energy storage, charging capabilities, size, payload, range, energy reserves and other various requirements that OEMs should consider when designing and building AAM purposed aircraft (“UberAir Vehicle Requirements and Mission”, 2018). An example of research on the more technical side of this issue was the study entitled “Strategies for Posing a Well-Defined Problem for Urban Air Mobility Vehicles”. In this article, Clarke et al. outline aircraft design strategies and identify design variables and constraints to assist in the optimal AAM aircraft design (2019). Johnson et al. in their work “Continuous Testing and Deployment for Urban Air Mobility” present technology that can bridge the gap between AAM aircraft development and operations (2020).

2.6.5.3 Regulation

Regulation is a broad obstacle for AAM integration because it encompasses the main three levels of policy making within the United States: federal, state, and local. AAM regulation will include Congressional laws, Federal Aviation Regulations (FARs), State laws, and city laws or ordinances. The FAA is of course involved with the efforts around AAM, and it has now gained additional traction at the Congressional level. In November of 2021 H.R. 1339 – Advanced Air Mobility Coordination and Leadership Act was passed in the House of Representatives and passed to the Senate of the United States. This Act requires the Secretary of Transportation to organize a multi-agency working group dedicated to review the current state of AAM and then to plan and offer up recommendations to Congressional committees (“H.R. 1339 – Advanced Air Mobility Coordination and Leadership Act”, 2021).

States and cities are engaging with the concept of Advanced Air Mobility and looking for direction on how to proceed. Because regulation is such a broad topic, it is often included as at least a subtopic of research within many AAM related pieces of literature. This research does aim to offer general next steps towards creating a regulatory framework at the local and state level.

2.6.5.4 Unmanned Aircraft System Traffic Management

In May of 2018 the FAA released the first version of the Concept of Operations document concerning Unmanned Aircraft Systems Traffic Management (UTM). In March of 2020 the updated second version of this document was published. This document provides an overview of the current efforts of the FAA and their collaboration with NASA. It outlines the evolution and capabilities of UTM, the benefits of a UTM system, the infrastructure necessary for UTM, and other factors such as operations, safety, security, and equity (Federal Aviation Administration, 2020). The use of UTM closely overlaps with another key obstacle which is airspace integration. A reliable UTM system helps meet the goal of high volume, safe low-altitude AAM operations.

2.6.5.5 Concept of Operations and Airspace Integration

In June of 2020 the FAA released their initial and currently the latest version of the Concept of Operations (ConOps) for Urban Air Mobility. The document outlines how the FAA currently views how AAM and UAM operations can integrate into the existing National Airspace System. It introduces the concept of UAM Corridors being used in conjunction with UTM managing low altitude operations, all within the larger context of the current Air Traffic Management rules that currently governs all manned and unmanned aircraft operations (Federal Aviation Administration, 2020). Figure 16 is from the UAM ConOps 1.0 document and depicts this discussed present line of thinking.

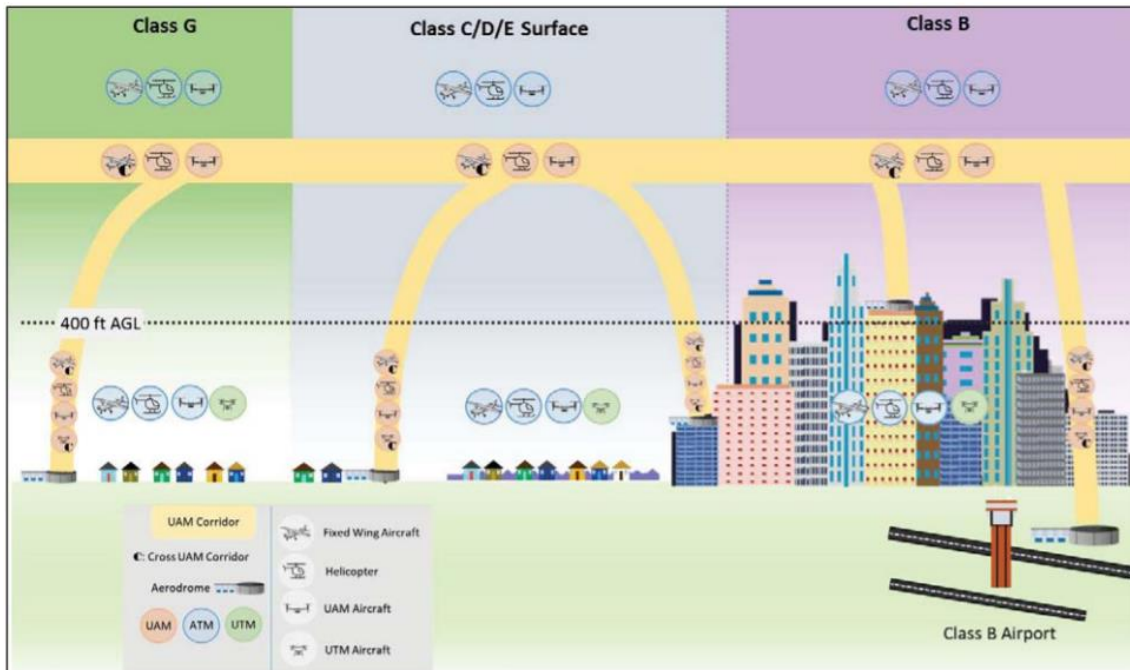


Figure 16: Current Depiction of FAA Concept of Operations for UAM (Federal Aviation Administration, 2020)

In addition to this document from the FAA, there is a large pool of literature on the topic of AAM airspace integration. In 2018 Kleinbekman et al. published a paper discussing that a key component of integration will be the arrival and departure sequencing of eVTOL aircraft in and out of urban centre vertiports and already busy commercial airports (2018). One of the more popular potential use cases of AAM is an airport shuttle to and from larger airports. Vascik and Hansman conducted a study in 2019 assessing how AAM operations could integrate with conventional operations in the airspace over the international airports in San Francisco, Boston, and Atlanta (2019).

Also in 2019, Cotton published his study that expands on the current FAA and NASA concept of operations concerning airspace integration and the role of UTM (Cotton, 2019). The technology industry has also weighed in, in 2020 a group from Intel Corporation published their study regarding the role of compute and communications technologies (COTS) which is inclusive of how new chips can assist in the seamless and reliable communication system necessary for between UTM, ATM, and emerging AAM operations (Athavale et al., 2020).

These are just a few examples of the many research projects that have been published on the broad and complex issue of AAM airspace integration.

2.6.5.6 Public Acceptance

Public acceptance is often thought about as the biggest piece of community integration of any new technology. While public acceptance is a key part of the overall adoption of AAM, it is noted here as a stand-alone obstacle, separate from the other factors of community integration. This is because as noted before, it is an obstacle worthy of a thorough, in-depth study in and of itself. There are many lessons that can be learned from the traditional aviation industry and the public acceptance challenges over the years related to aircraft noise, airport location, and aviation emissions. There is also a host of literature on general best practices surrounding public acceptance of emerging ideas or technologies across numerous industries. A Google Scholar search of “Public Acceptance Best Practices” returns over 2.3 million results.

An example of recent research dedicated to this specific AAM challenge of public acceptance is the 2022 work by Cetin et al. entitled “Implementing Mitigations for Improving Societal Acceptance of Urban Air Mobility”. This study specifically focuses on the psychological fears that people have around AAM technologies. The study identifies the top concerns and proposes mitigation practices that can be employed to assist in the eventual public acceptance of AAM (2022).

2.6.5.7 Ground Infrastructure and Community Integration

AAM ground infrastructure is once again, another example of a wider issue that encompasses many other obstacles that are all interwoven into the greater issue at hand. Ground infrastructure such as vertiports will be built at the city level in communities across the world, this makes community integration of AAM a top issue to be explored as it relates to ground infrastructure. In June of 2020 an article was published in the Journal of Air Transport Management entitled, “An overview of current research and developments in urban air mobility – Setting the scene for UAM introduction”. The contribution of this article was to categorize and identify the current research being conducted on various aspects of AAM. One of the categories noted is ground transportation, Straubinger, et al. said the

following concerning this category, “there is only little research on UAM ground infrastructure, despite its relevance for the highest-risk flight phases, namely take-off and landing, and in terms of vehicle throughput and accessibility” (2020, pg. 5). The ground transportation section of this article goes on to cite only four unique studies related to the topic, which have all been referenced above in various sections. A common theme across these four studies was vertiport placement and vertiport capacity. These are important components of the ground infrastructure obstacle, but the research gap can be seen once again on the multifaceted, greater ground infrastructure issue. In present society one cannot build much of anything without a series of interactions with the local authority.

For example, if one wishes to build a house, they will need to first meet with a licensed architect who can provide them a set of house plans. These house plans will then be submitted to the local municipality for review and approval. Once the plans are approved the land will likely be inspected and approved for the building itself. The municipality will then provide a building permit specific to the approved house building project. Throughout the course of the project the home will be inspected multiple times by licensed construction inspectors who ensure the house is being built to local code. The owner of the home is often restricted by law from occupying the house until all inspections have been passed satisfying the demands of city regulations and a certificate of occupancy is issued. This example is to demonstrate just how involved the process is concerning local authorities when just building a home. The general idea for private commercial projects is the same but only grows in complications, the number of regulations involved, and required planning time. The implications of local and state laws increase exponentially when the commercial project concerns public services like transportation. See Figure 19 that demonstrates the multi-step urban planning process that the building of commercial UAM ground infrastructure will need to go through. These planning stages are often on 5 to 10-year planning cycles.

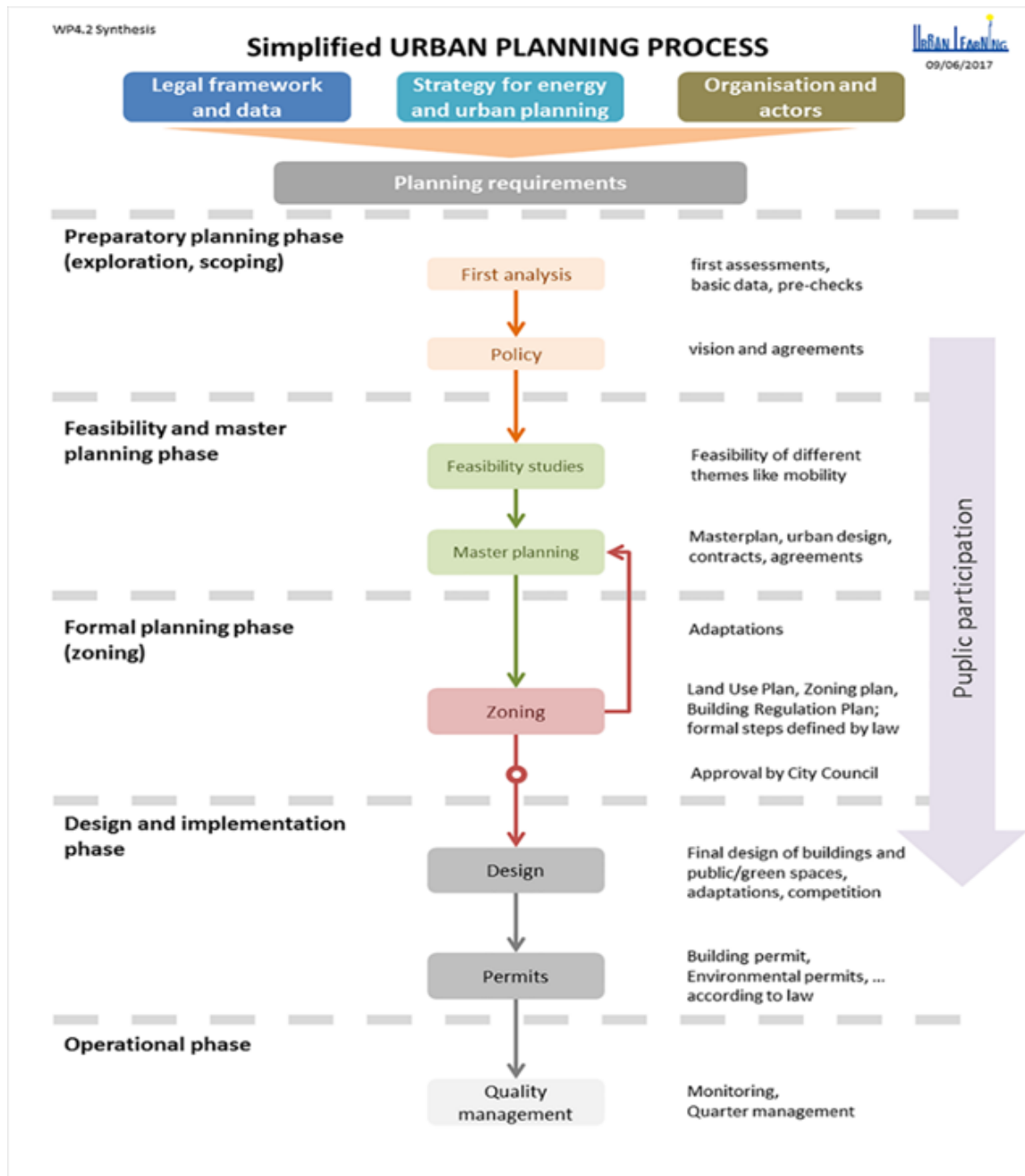


Figure 17: Urban Planning Process (Urban Learning, 2007)

Immel and Langlinais in their article “The Challenges to Urban Air Mobility” predict that these very building processes and the power of local cities concerning zoning and awarding building permits will perhaps be the largest obstacle when it comes to UAM ground infrastructure (2020). Often city authorities withhold building permits, change zoning, or pass local laws, code, or ordinances that block progress of a project because of the influence of the

public. This raises the issue of public acceptance. Public acceptance is not a new issue, especially when it comes to aviation. This public acceptance hurdle and its relation to city authority and urban planning is perhaps one of the most crucial pieces to the overall success of UAM integration, yet there is little to no literature addressing this. For the purposes of this research this crucial piece and research gap is defined as “community integration”.

While manufacturers continue to make large strides of progress seemingly few efforts are being made to advance the physical infrastructure cities will need to accommodate UAM aircraft (Lineberger et al., 2019). Significant amounts of time will be necessary to complete the multi-step planning and building process required for UAM infrastructure. Because certification of UAM aircraft is likely by 2024 it is anticipated that existing aviation infrastructure in the way of heliports, regional airports, and small/medium hub airports will initially be used. For the full anticipated benefits of UAM integration to be realized there a few key points in the current literature related to this issue of community integration.

One of the first items needed to begin progression of UAM ground infrastructure in cities is a consensus on a concept of operations. Although ground infrastructure inventory and future needs will vary city to city, general use cases and operations will likely exist across the industry. One potential starting point for cities at these beginning stages is to perform a comprehensive assessment of existing infrastructure and potential future sites. These assessments should be completed through the lens of existing regulations across planning, design, and operations (Lineberger et al., 2019). As cities take an initial look at UAM it is critical to approach it from an intermodality standpoint, meaning the need for the city air transportation network to seamlessly connect to other modes of transportation such as rail, subway, busses, cars, bikes, e-scooters, etc. (Cohen, 1996).

Historically government regulations are a reaction to technology disrupters, UAM can be different if policy makers will engage now with leading industry stakeholders to develop policy next steps together (World Economic Forum, 2020). Local governments are best suited to provide the necessary information

to understand the needs, challenges, and concerns of their neighbourhoods. Collaboration between these local government agencies, the community itself and industry, academia, and federal agencies will be pivotal to the advancement of AAM (Prichard et al., 2020). Cities could create an “integrated aerial vehicle authority” to lead local efforts on addressing questions surrounding ground infrastructure, UTM, and the city’s current position for integrating UAM (Lineberger et al., 2019).

An example of initial attempts at the local level can be seen from the city of Los Angeles, California which has been proactive in starting a collaborative effort between the city mayor’s office, the city department of transportation, and the World Economic Forum. This local multi-agency effort also worked with federal government agencies such as NASA and the FAA. The results of these combined efforts were published in September 2020 in a report titled “Principles of the Urban Sky” released via the World Economic Forum (World Economic Forum, 2020). This report offers seven UAM principles: safety, sustainability, equity of access, low noise, multimodal connectivity, local workforce development, and purpose-drive data sharing. These high-level guiding principles are a result of feedback provided from public and private stakeholders via interviews, workshops, and varying academic research. These UAM principles have been offered to serve as a foundation to local policy making regarding the UAM integration (World Economic Forum, 2020).

Another example can be found in a use-case study implemented by Uber Air under the UberCopter operations in New York City, New York. In an effort to do market research for urban aviation transportation, UberCopter began flights in 2019 providing air service between Lower Manhattan and the John F. Kennedy International Airport (“Introducing Uber Copter”, 2019). This transportation service was multi-modal as it included a seamless transition from an Uber car to the helicopter and back to an Uber car all through the use of a phone app. When Uber prepared to launch this unique service, it was designed with the community in mind. Considerations around safety, hours of operation, the market, and feedback channels were heavily researched. Uber engaged the community

through local elected officials, policy makers, community groups, local aviation authorities, federal aviation authorities, and local academic institutions. Uber leaned heavily on principles from the International Association for Public Participation, also known as IAP2 (Prichard et al., 2020). The focus of IAP2 is to “achieve effective community and stakeholder engagement (or public participation)” (“About IAP2”, 2019). IAP2 has produced a variety of resources and guidance for how to properly engage the public. One of these resources is the “Public Participation Spectrum” which outlines the differing degrees of public participation and the public relationship with the primary organization. See Figure 18 that depicts the Public Participation Spectrum concept.

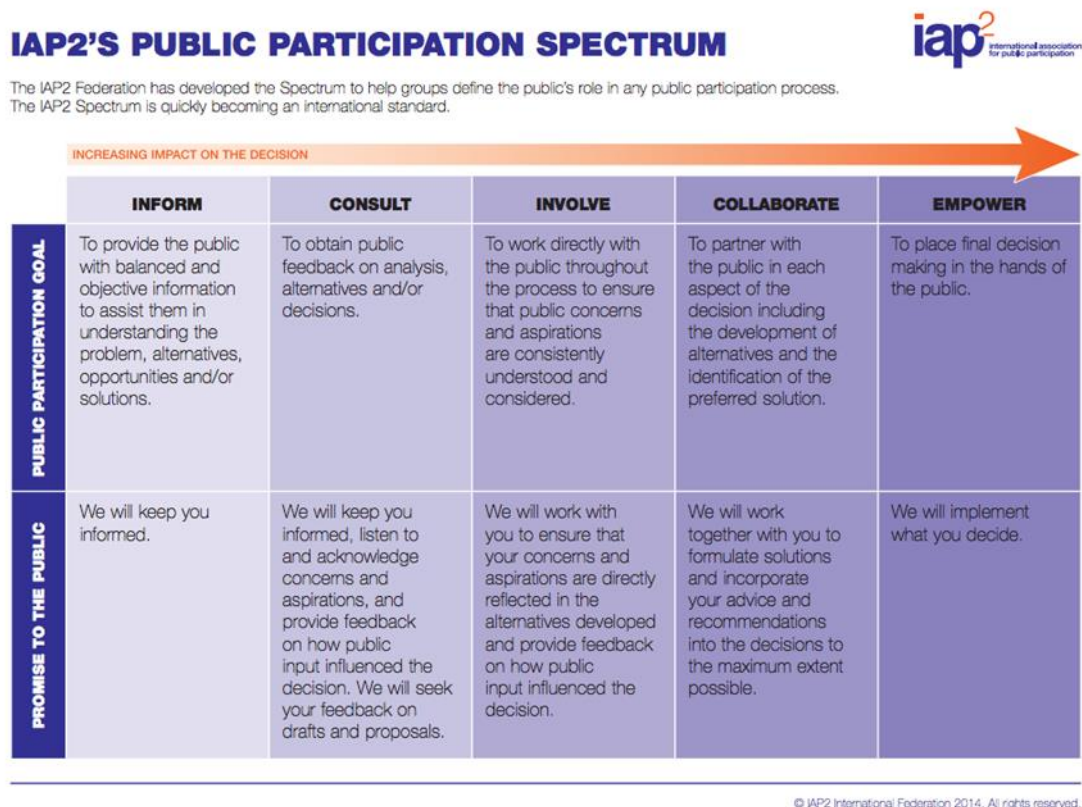


Figure 18: Public Participation Spectrum (International Association for Public Participation, 2015)

2.7 Literature Gap

While the current literature brings attention to some general essential points and offers up principles, numerous questions remain regarding the details of next steps to be taken towards true community integration of AAM specifically. Questions around the location of vertiports, land use laws, zoning, municipal code, the role of urban and transportation planners, funding, vertiport ownership/operator, stake holder engagement, public awareness and acceptance, and social equity. There is simply no “how-to manual” on the best place to start, or what the initial phases should include, and what a city or state should do concerning community integration of AAM.

Tremendous progress is being made on various fronts concerning Advanced Air Mobility and the forecasted use cases and potential benefits to our lives. But immense obstacles remain in the way of full integration of these technologies, while many of these barriers are being researched the issue of community integration stands with a large research gap. The aim of this research is to develop a more detailed framework of next steps that will provide utility to city planners, transportation planners, aviation planners, state and municipality governments and agencies when integrating Advanced Air Mobility into their communities.

3 Methodology

The literature review established that, AAM ground infrastructure is one of the leading obstacles to overcome when integrating UAM into the transportation system. The planning and building of any transportation infrastructure is a lengthy process, and therefore, as new eVTOL aircraft approach certification status it is critical to better understand how to prepare for AAM infrastructure. The aim of this research is to develop a framework that will provide utility to city planners, transportation planners, aviation planners and municipality governments when integrating Urban Air Mobility into their community. Because the process of adopting AAM into a city or regional transportation network is nuanced and there are many unknowns, qualitative data regarding the process needed to be collected and analysed.

A challenge of the Advanced Air Mobility industry is its fast-evolving nature due to the rapidly advancing technologies. The industry has experienced significant growth with hundreds of companies working on AAM products and services while hundreds of new design concepts continue to surface (Vertical Flight Society, 2021). In the year of 2021 the industry saw an additional \$7 billion in investment, several leading AAM companies went public, and large traditional aviation players, such as manufacturers and airlines, became more actively engaged (Esqué & Riedel, 2022). The seemingly continual growth and change within the AAM industry makes it difficult for cities or regions to find their bearings in the planning process of how to integrate AAM into their transportation systems. The methodology used for this research seeks to cut through those difficulties and aims to identify themes such as anticipated consequences, stakeholder roles, and keys for success to create a flexible structure of next steps.

The research method adopted was thematic analysis, which is a method for analysing a qualitative dataset and identifying the recurring themes or patterns from the data. The method is inclusive of describing and interpreting the data through a coding process and constructing themes and sub-themes (Kiger & Varpio, 2020). Thematic analysis has not always been respected as an independent research method, rather it was originally treated as something

simply to help researchers using other qualitative research methods such as grounded theory, ethnography, or phenomenology (Nowell et al., 2017). This has drastically changed in the last two decades with the pioneering work of psychologists Virginia Brawn and Victoria Clarke whose 2006 paper “Using thematic analysis in psychology” has been cited over 120,000 times (Google Scholar, 2022). Brawn and Clarke have gone on to write books on using thematic analysis, their work has established the thematic analysis research process as one that can be used as a standalone rigorous methodology across countless fields of research (Kiger & Varpio, 2020). The widespread use of the approach across industries includes the Aviation and Aerospace industries, a Google Scholar search delivers over 12,000 references of thematic analysis studies related to air transportation.

Other types of common qualitative research such as phenomenology, ethnography, and grounded theory were explored, but ultimately thematic analysis was selected as the suitable approach to meet the original research aim because of its pliable approach. Phenomenology is to work towards understanding a phenomenon, this is done by understanding the experiences of people (Neubauer et al., 2019). At this stage of the AAM movement, phenomenology was not the best research approach to answer the original research questions. Although the AAM movement may be considered a technology phenomenon, using phenomenology as the primary research method would not be appropriate at these beginning stages of AAM. This is because phenomenology relies heavily on understanding human experiences related to the phenomenon itself. Perhaps once people utilize AAM in their lives this would be a better suited methodology for understanding how to improve AAM.

Ethnography is another common method used within qualitative studies but as it is the study of group cultures it would not have served well in this project (Hammersley, 2006). Ethnography originally comes from anthropology which is to study the development of human societies and cultures. A core principle when using ethnography is field work and observation of lived experiences. Again, at the early stages of AAM it would be difficult to observe lived experiences related

to AAM. Ethnography is better suited to understanding why people act the way they do within various cultures and was not a viable option to meet the needs of the research objectives.

Grounded theory is the most like thematic analysis but ultimately has notable differences. Grounded theory is a research method with the goal to develop a new theory about why a particular phenomenon happens that is grounded in data that has been systematically collected, coded, and analysed (Noble & Mitchell, 2016). Grounded theory does not allow for the consideration of other literature or theories on the phenomenon in question, the methodology is used to develop the new theory as to why something is happening. Similarly, to thematic analysis there can be multiple approaches to a coding system while using grounded theory, but an overarching practice of grounded theory is to take an inductive approach (Mills et al., 2006). This inductive approach means the researcher must allow the theory to organically come from the data, rather than starting with a theory and wanting the data to confirm the pre-developed theory.

Grounded theory and thematic analysis employ similar systems to collect, code, and analyse data to identify a theory or themes but they do have differences. One difference is that grounded theory returns to the data throughout the ongoing process of developing a new theory, whereas thematic analysis waits for all data to be collected before the coding process begins. But the main difference between the two methodologies is grounded theory is a narrow approach to developing a theory to answer why something is happening or to explain a particular phenomenon. While thematic analysis can be used in a similar way it provides more flexibility as to the research questions it can address and the ways it can be used (Kiger & Varpio, 2020). This flexibility allows for thematic analysis to be used to explain how something can happen, to help in creating frameworks. Grounded theory can't be used in that way and is used purely for developing a new theory on why something has happened. For these reasons, thematic analysis was selected as a better methodological approach to meet the research aim and objectives.

Thematic analysis is an adaptable research approach and can produce an in-depth and complex report of the data (Nowell et al., 2017). The methodology provides tremendous utility in thoroughly investigating the differing perspectives of study participants, identifying the agreements and disagreements, connecting foundational ideas to generate themes that can be used in creating frameworks of understanding or of actionable items. Due to the evolving nature of the AAM industry and the project aim to provide a framework of next steps, these strengths of thematic analysis made it the best-chosen approach.

The freedom thematic analysis provides which can serve as an advantage, can also be seen as detrimental and the overall approach viewed as less than if the researcher does not properly outline and follow a rigorous process. The research data and findings can fall short on quality if the flexibility is taken to an extreme. Although these are potential downfalls of thematic analysis, these possible disadvantages can be properly mitigated to produce quality findings.

As the qualitative research field grew various criteria were developed to grade the research quality. In the early 1980s, Guba and Lincoln established a system for grading the rigor or trustworthiness of qualitative research. By 1985 they defined the categories to be considered to produce a trustworthy qualitative work, these categories are credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). Credibility is to establish confidence in the findings, transferability is demonstrating how the findings can have applicability in various contexts, dependability is proving the consistency of the findings and could be repeated, and confirmability demonstrates a state of neutrality, the ability to show the findings are from the participants rather than the researcher's bias (Lincoln & Guba, 1985). These criteria will serve as guiding principles throughout the execution of this thematic analysis.

3.1 Thematic Analysis Process

Prior to starting any portion of the thematic analysis process research integrity and research ethics were fully considered. Research integrity as defined by Cranfield University policy refers to high quality and robust practice across the full research process i.e. the planning and conduct of research, the recording and

reporting of results, and the dissemination, application and exploitation of findings. Once thematic analysis was the chosen methodology, the foundations of research integrity were reviewed and implemented as the systematic process to be followed was designed. Research ethics is further discussed in section 3.1.4. Figure 21 outlines the robust systematic process that served as the guide to completing a thorough thematic analysis for this project.

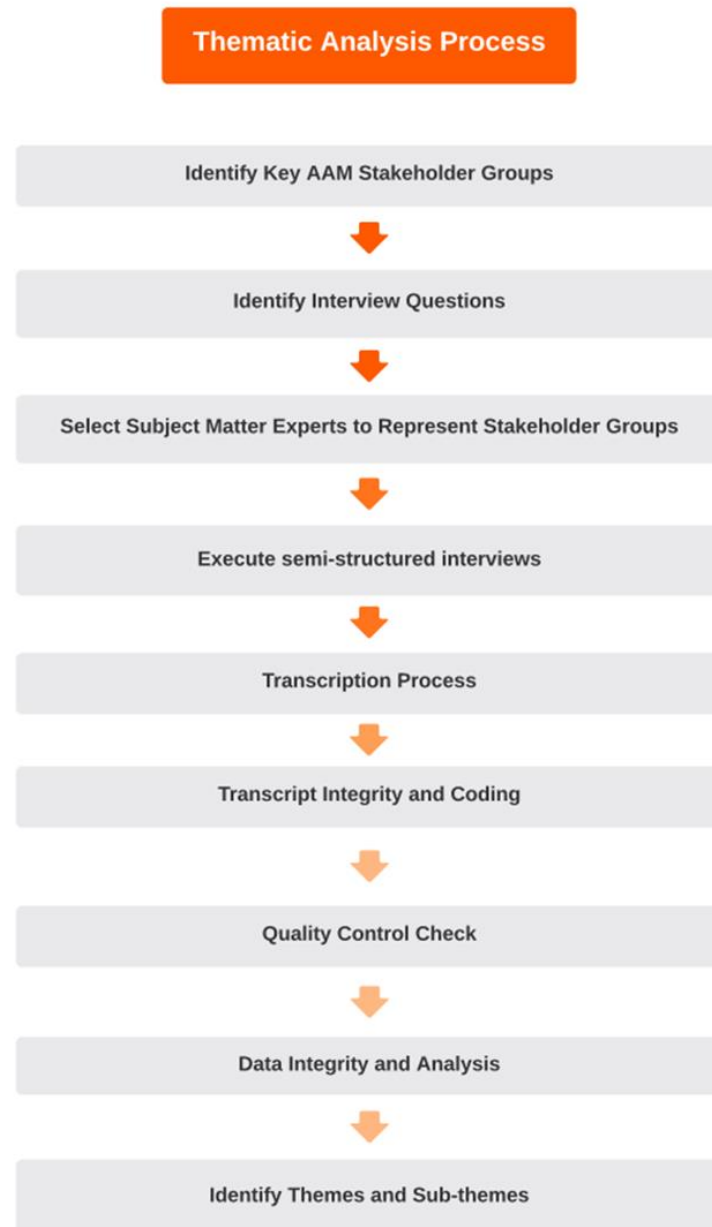


Figure 19: Thematic Analysis Process Depiction (Author)

3.1.1.1 Identified Key AAM Stakeholder Groups

The first step in the process was to identify Key AAM Stakeholder Groups that would have major roles in the development, planning, regulating, and integration of AAM into communities. There are potentially hundreds of stakeholders that will eventually take an active role in the adoption of AAM, but at this stage in the overall process it was important to select only the initial, major players. For the sake of this research not every stakeholder group was referring to a group of people or organizations, rather some stakeholder groups refer to a particular discipline related to AAM. The groups identified and selected were as a result of the literature review and through the lens of the original research aim and associated research objectives.

The literature review greatly assisted in identifying what these Key Stakeholder Groups should be. Figure 1 in section 2.1 laid out the literary scope, upon completion of the literature review it was determined that several of the seven noted obstacle groups that had emerged from the literature could be combined into Key Stakeholder Groups. For example, Aircraft Certification was combined with Regulation and Unmanned Aircraft Traffic Management System was combined with Concept of Operations. Five of the eight represented Key Stakeholder Groups came directly from the literature review: Market Demand, Regulatory, Ground Infrastructure, Concept of Operations and Community Integration. The other Key Stakeholder Groups were identified through the research objectives in order to have proper representation to ultimately meet the outline research objectives. below is a list of the identified Key AAM Stakeholder Groups:

- Market Demand
- Regulatory
- OEMs
- Ground Infrastructure
- AAM Concept of Operations

- Community Integration
- City Servant
- Transportation Planning
- Airports

3.1.2 Identified Interview Questions

After the Key AAM Stakeholder Groups had been identified the next step was to develop interview questions to be used to extract information from subject matter experts (SMEs) that would be useful towards meeting the original research objectives. The chosen interview approach was semi-structured meaning that the 16 developed questions were written in an open-ended format to encourage participants to freely share their thoughts. The interview questions are included in Appendix A.

The questions are based in part on the review of the literature and focused on the areas where the literature gap had been identified, namely, AAM ground infrastructure and its integration into a city transportation system, discussed in Section 2.7. For example, as the literature review was completed it became clear that the overall integration piece and what keys are necessary is truly important. Questions five, six, seven, nine, twelve and sixteen from the interview question list each work to address research objective three which is identifying these success keys to AAM integration.

Other questions were designed to add to the current literature, for example questions one and two tie back to defining terms discussed in Sections 1.1 and 2.6.1. As the definitions of AAM and UAM differ from person to person in this ever-changing environment it was important to establish definitions up front. Another example are questions three and four relate to the early use cases of AAM that were discussed in Section 2.2.2 of the literature review.

3.1.3 Selected Subject Matter Experts

The search for qualified SMEs that could represent potential AAM stakeholder groups really started at the beginning of this research project. Although an exact methodology had not yet been selected, collecting qualitative data from AAM experts was a key piece of the research from the foundations of the project. For two years as potential experts surfaced through the literature, through industry conferences, and other personal networking means they would be noted on a list along with their area of expertise and contact information. Once the Key Stakeholder Groups had been identified, the list of close to 50 potential candidates was analysed. As the list was sorted against the groups, each group contained multiple potential experts that could be contacted as needed. A primary SME was identified within each Key Stakeholder Group based on their career background, AAM experience, involvement, and/or publications. The primary candidate across many of the groups agreed to participate in the study, while a few of the groups required seeking the participation of the backup SME due to scheduling conflicts or lack of permission to participate.

Of the nine original Key Stakeholder Groups, only eight groups were ultimately represented within the study. Efforts were made with multiple city servants who were familiar with AAM but in the end no one was secured in time. One individual from the FAA initially agreed to participate and an interview was scheduled, minutes before the interview he sent an email noting he could no longer participate. Another individual was contacted from the FAA, but he too eventually declined to participate. The potential reasoning these individuals or agencies were unable to participate is due to the vast uncertainties that come from currently being in the early stages of AAM adoption. The Regulatory stakeholder group was represented at the state level, which in the end added more valuable context to creating a regional framework forward with AAM. Below is a list of the Key AAM Stakeholder Groups and the anonymized SME who ultimately represented each group.

- **Market Demand** – individual with 30+ years of industry experience and has completed multiple location specific AAM market studies around the world

- **Regulatory** – experienced state aviation director from one of the 50 United States
- **OEMs** – mid-level manager at one of the leading OEMs with 20+ years of aviation regulatory and legal experience
- **Ground Infrastructure** – individual with 40+ years of industry experience, current CEO of a global aviation ground infrastructure consulting firm
- **AAM Concept of Operations** – a highly established published author in AAM literature on a holistic AAM system
- **Community Integration** – individual with 20+ years industry experience, 5+ years of AAM community integration work, now within one of the largest US cities
- **Transportation Planning** – city transportation planner with 15+ years of planning and operational experience working with a proactive AAM city in the US
- **Airports** – individual with 25+ years of airport operational experience, is currently serving as the airport director of a medium hub US airport

3.1.4 Executed Semi-structured Interviews

Research ethics as defined by university policy are a subset of research integrity, focusing on the principles of avoidance of harm, within a statutory and regulatory framework. All research must have appropriate ethical approval; this research and chosen methodology were approved based on the ethical considerations and chosen protections for participants.

The focus of how to avoid harm to participants was to be completely transparent and provide each participant all of the information of how they would participate, how the data would be used, and what protections were available to them. As part of the previously constructed Data Management Plan and ethical considerations as study participants agreed to participate, they were sent the Informed Consent form, this form is included in Appendix B. The Informed Consent form outlined their agreement to participate in the study and outlined in detail how their interview would be recorded, transcribed, and then analysed as part of the larger dataset. Interview participants were given the choice whether

their interview transcript would be fully anonymized or pseudo-anonymized by still allowing reference to their professional role. This form served as an agreement between participants and the researcher, allowing for mutual trust and understanding.

The next step within the process was interviewing the participants using the semi-structured interview method. The use of interviews is a frequently used qualitative data collection method; there are three types of interviews: structured, semi-structured, and unstructured (Mathers et al., 1998). Structured interviews mean asking the same exact questions, in the same exact order to all of the participants, maintaining strict adherence to the interview guide. Semi-structured interviews contain open-ended questions that can be asked in various orders from participant to participant. Semi-structured interviews are more conversational and allow the interviewer to add questions as the conversation dictates. Although it is less structured, this style of interview still requires great preparation and planning to properly execute quality data collection (Mathers et al., 1998). Unstructured interviews focus on a series of topics to discuss but typically do not have defined questions prior to the interview.

Because the research aim of this project was to provide a general framework of AAM next steps on the local level, it was determined that semi-structured interviewing for data collection would be the best. Semi-structured interviewing allows the interviews to be focused while still giving the researcher the flexibility to dive deeper on relevant topics that come up in the interview discussion (Adeoye-Olatunde & Olenik, 2021). The semi-structured method is ideal for exploring the participants thoughts on complex open-ended questions, leading to a rich dataset.

All eight SME interviews were conducted via Microsoft Teams where both video and audio were recorded from the start of the interview questions, through to the completion of said questions. The interviews ranged in length from 45 minutes to 1 hour and 30 minutes, while the average interview length was 55 minutes.

3.1.5 Transcription Process

Upon completion of the interviewing process, the transcription process was able to take place. Each interview video recording file was uploaded into InqScribe transcription software and manually transcribed one by one. This manual transcription process was time consuming but allowed for great familiarity with the data while also producing the most accurate transcripts possible.

3.1.6 Transcript Integrity and Coding

Once transcription was complete each transcript was reviewed for transcript integrity. This involved reading each line of the transcript, correcting grammatical errors, and referencing the original interview recording where content clarification was necessary. At this time in the process each transcript was formatted in preparation for the coding process.

Qualitative data coding of interview transcripts can be done in a variety of ways. Coding can refer to numbers being assigned to various words or phrases, or can be a system of abbreviations, or using words and short phrases to describe bits of data. In qualitative coding there are two categories of code: a priori codes and empirical codes. A priori codes would be codes that are defined prior to conducting any data collection, typically related to categories that the researcher expects to have confirmed. Whereas empirical codes are codes created after data collection while analysing the dataset (Gibson & Brown, 2009).

Combining the use of empirical codes with an inductive approach ensured that themes could be derived from the participants and the collected data. A deductive approach would mean approaching the data with a predetermined framework and seeking confirmation within the data. This project used the inductive method to extract themes from the dataset, it is important to note that because the themes are data driven, they will not necessarily always directly relate to the original interview questions. For example, if the participants expounded on an answer or to enrichen the understanding the interviewer asked follow-up questions leading to new topics (Kiger & Varpio, 2020). These types of things result in data not directly traceable to the original 16 questions on the interview guide.

To allow new ideas or themes to emerge from the dataset, the empirical coding system was employed as short phrases were assigned to various segments of data from the transcripts, these brief phrases served as the codes. Each transcript was formatted for coding by placing the transcript in a left-hand column and the codes being noted in a right-hand column. Each transcript was carefully read, ideas and concepts would be highlighted in the transcript on the left and then a corresponding code assigned and noted on the right. In Figure 20 below is an excerpt from one of the coded transcripts to demonstrate this process. The arrow points to an assigned code that can be seen in the data shown in Figure 21. All 160 formatted pages from the eight transcripts underwent the same coding process. The dataset produced 835 total codes that proceeded to additional analysis.

<p>It only works if we work together, that within the network that there are places for these to go and if we pull together then we have a much better chance of getting better integration within our community then if we just stay in our own silo all trying to make up our own rules. To be fair to the industry, they will just complain enough that there will be pressure on the state or federal level where they will come in and say there are</p>	<p>AAM “success key” – collaborating and working together across the board</p>
<p>just too many different rules out there...this can’t work, and we are just going to step in and make rules about A, B, and C. But if we come in and make a general framework and work together to set some of that, if it is a faster process and it works okay for the industry then they are usually happy to go along with it. They want to be able to operate, be able to come to communities and have that path forward. So, we need to set that path that also helps us by really working together, it is the only way to do that.</p>	<p>AAM “success key” – creating the regulatory framework and general plan in collaboration</p> <p>City role – working with surrounding cities and working together to create the path forward</p>

Figure 20: Coded Transcript Example (Author)

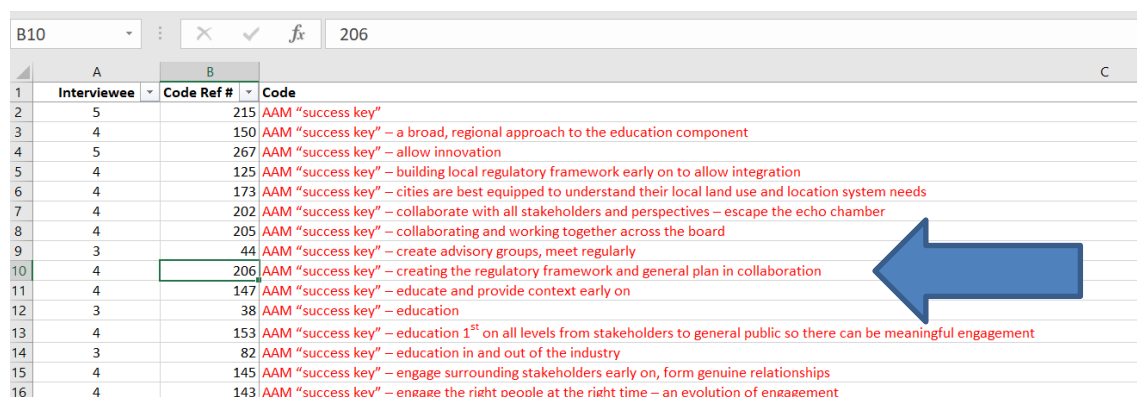
3.1.7 Quality Control Check

Once two transcripts had been coded, they were sent to an experienced, independent researcher who is familiar with Advanced Air Mobility. This

researcher read the transcripts and correlating codes that had been assigned to the segments of data. The researcher was to note if they would change any of the given codes to differently express the original ideas or thoughts of the interviewees. This quality control check or auditing process of an independent researcher was in an effort to meet the credibility and confirmability criteria of trustworthy qualitative research (Stenfors et al., 2020). The researcher confirmed the coding process and felt the assigned codes were appropriately representing the primary data.

3.1.8 Data Integrity and Analysis

The 835 codes from the coding process were placed into a Microsoft Excel Workbook to be further analysed. Each code was assigned a code reference number, 1 through 835, and each code was given an interviewee reference number to trace back to the original transcript. After these reference numbers had been allocated, the codes were sorted by alphabetical order. Figure 21 shows an excerpt from the Excel document to show an example of how the 835 codes were initially organized. This example correlates to Figure 20 where it shows what was said in the interview and the code which was assigned. That code appeared in the organized data on line 10 with the Code Reference Number of 206, which can be seen in Figure 21.



	A	B	C
	Interviewee	Code Ref #	Code
1			
2	5	215	AAM "success key"
3	4	150	AAM "success key" – a broad, regional approach to the education component
4	5	267	AAM "success key" – allow innovation
5	4	125	AAM "success key" – building local regulatory framework early on to allow integration
6	4	173	AAM "success key" – cities are best equipped to understand their local land use and location system needs
7	4	202	AAM "success key" – collaborate with all stakeholders and perspectives – escape the echo chamber
8	4	205	AAM "success key" – collaborating and working together across the board
9	3	44	AAM "success key" – create advisory groups, meet regularly
10	4	206	AAM "success key" – creating the regulatory framework and general plan in collaboration
11	4	147	AAM "success key" – educate and provide context early on
12	3	38	AAM "success key" – education
13	4	153	AAM "success key" – education 1 st on all levels from stakeholders to general public so there can be meaningful engagement
14	3	82	AAM "success key" – education in and out of the industry
15	4	145	AAM "success key" – engage surrounding stakeholders early on, form genuine relationships
16	4	143	AAM "success key" – engage the right people at the right time – an evolution of engagement

Figure 21: Excel Example of Referenced Codes (Author)

Due to the nature of the coding approach that had been employed there were principal codes of one to two words accompanied by phrases or sentences providing additional contextual details. Using an excel formula the principal codes

were separated from the description. These principal codes were then referred to as the themes.

To ensure data integrity each line of data was inspected and corrected as necessary for grammatical errors or other minor coding errors. Using the count function, the themes were analysed to see how frequent each theme appeared and to combine the same codes. From the 835 codes, there were only 21 original themes, which can be seen below in Figure 22.

	A	B
1	Theme	Count
2	AAM success key	152
3	Anticipated obstacle	141
4	City role	118
5	Anticipated benefit	86
6	Potential use case	65
7	Definition	44
8	Outstanding question	41
9	State role	34
10	Location matters	30
11	FAA Role	29
12	Industry role	19
13	OEM role	17
14	Timeline prediction	15
15	Airport role	12
16	Price point	12
17	Industry perception	5
18	AAM progress predict	2
19	External factor	2
20	NASA role	2
21	Public-private partners	1
22	Academia role	1

Figure 22: The 21 Original Themes with Correlating Counts (Author)

To conduct a deeper analysis, it was determined that another round of coding should be performed. This additional round of coding was of the remaining descriptions that had been separated from the themes, thus enabling another layer to the data. A subsequent column in the Excel sheet was created and

designated as sub-themes. All 835 descriptions were read and 639 of them were assigned a one- or two-word code to describe the sub-theme. The remaining 196 descriptions were not assigned a sub-theme as it would have been repetitive of the main theme. These sub-themes then underwent the same process as the themes, the count function was used to identify the reoccurring sub-themes. This count resulted in 71 unique sub-themes. As an example, the top 20 of these sub-themes and the correlating counts can be seen below in Figure 23.

	A	B
1	Sub-Theme	Count
2	Education	114
3	Collaboration	61
4	Equity	60
5	Public resistance	40
6	Integration	39
7	Revenue generation	35
8	Expensive	23
9	Regulatory	18
10	Plan for AAM	17
11	Local Regulatory Frame	13
12	Airport transfer	13
13	Job growth	13
14	Trust	9
15	Transparency	7
16	Limited resources	7
17	Moving Target	7
18	Thin haul	7
19	Outstanding questions	6
20	Technology limitations	6
21	Economical growth	5

Figure 23: Excerpt of Top 20 Sub-themes with Correlating Counts (Author)

4 Results

4.1 Themes and Sub-themes

The in-depth process of interviewing the key stakeholder SMEs, transcribing the interviews, coding the transcripts, and analysing the dataset resulted in the identification of main themes and sub-themes. A few of the 21 themes and many of the 71 sub-themes only occurred one to five time across the 835 original codes. It was determined to focus on the top eight themes and the top three to five sub-themes found under these eight themes.

The thematic analysis produced keys to the success of AAM, identified potential use cases, anticipated consequences, and outlined various stakeholder roles. Outlined in Figure 24 are the top recurring themes and Figure 25 outlines the top recurring sub-themes across the entire dataset.

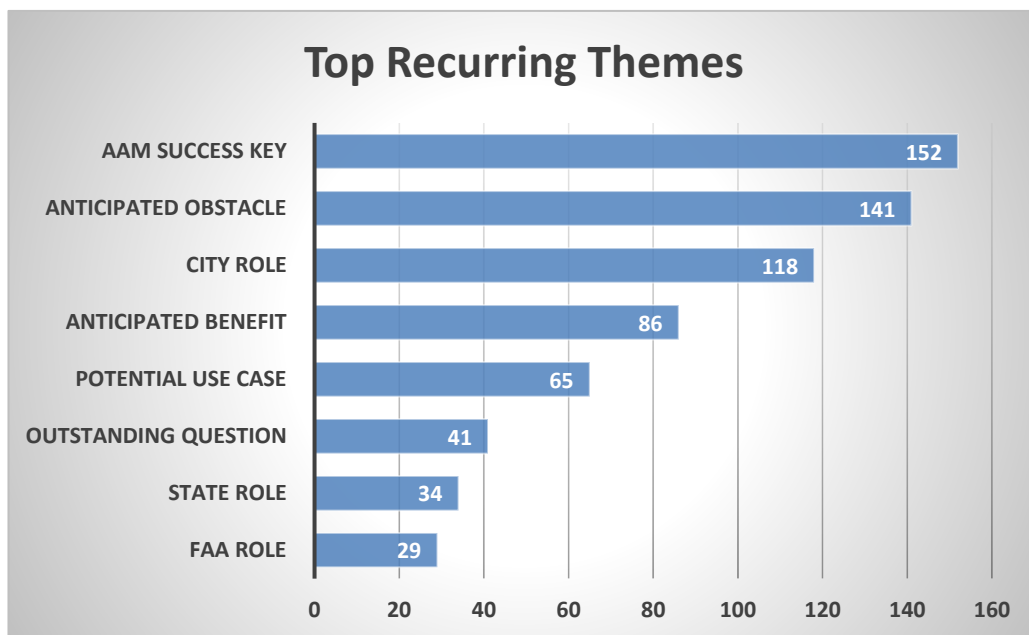


Figure 24: Top Recurring Themes (Author)

The top eight themes depicted in Figure X were further consolidated into five top themes. “Anticipated Benefits” and “Anticipated Obstacles” were combined under the term “Anticipated Consequences”. The city, state, and federal roles were combined under the term “Stakeholder Roles”.

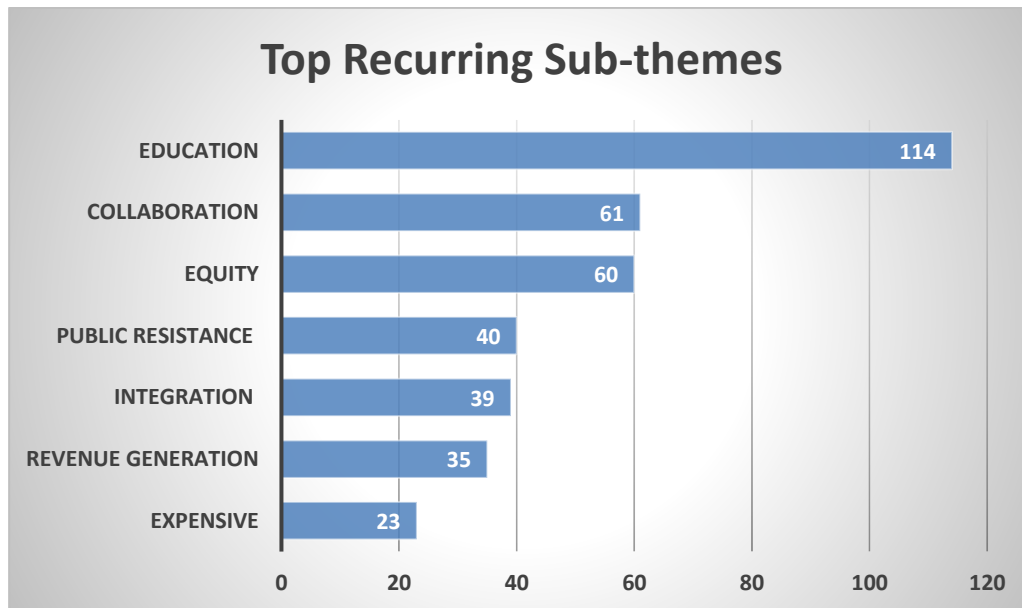


Figure 25: Top Recurring Sub-themes (Author)

It is important to note that although “Equity” was the third top recurring sub-theme across the entire dataset of 835 codes that it was not one of the most frequent sub-themes when the top three to five sub-themes were identified for the top five themes. While “Revenue Generation” was the sixth top recurring sub-theme across the dataset, it too did not appear as a top sub-theme through the lens of the five themes.

In Figure 26: Thematic Analysis Results, the top five themes and their leading sub-themes are depicted. Recurring Sub-themes and other connections are colour coded across the themes. The less obvious connection is depicted using light purple, these are considered overarching successes if true AAM integration can be complete, these are discussed more in Section 4.6.5.

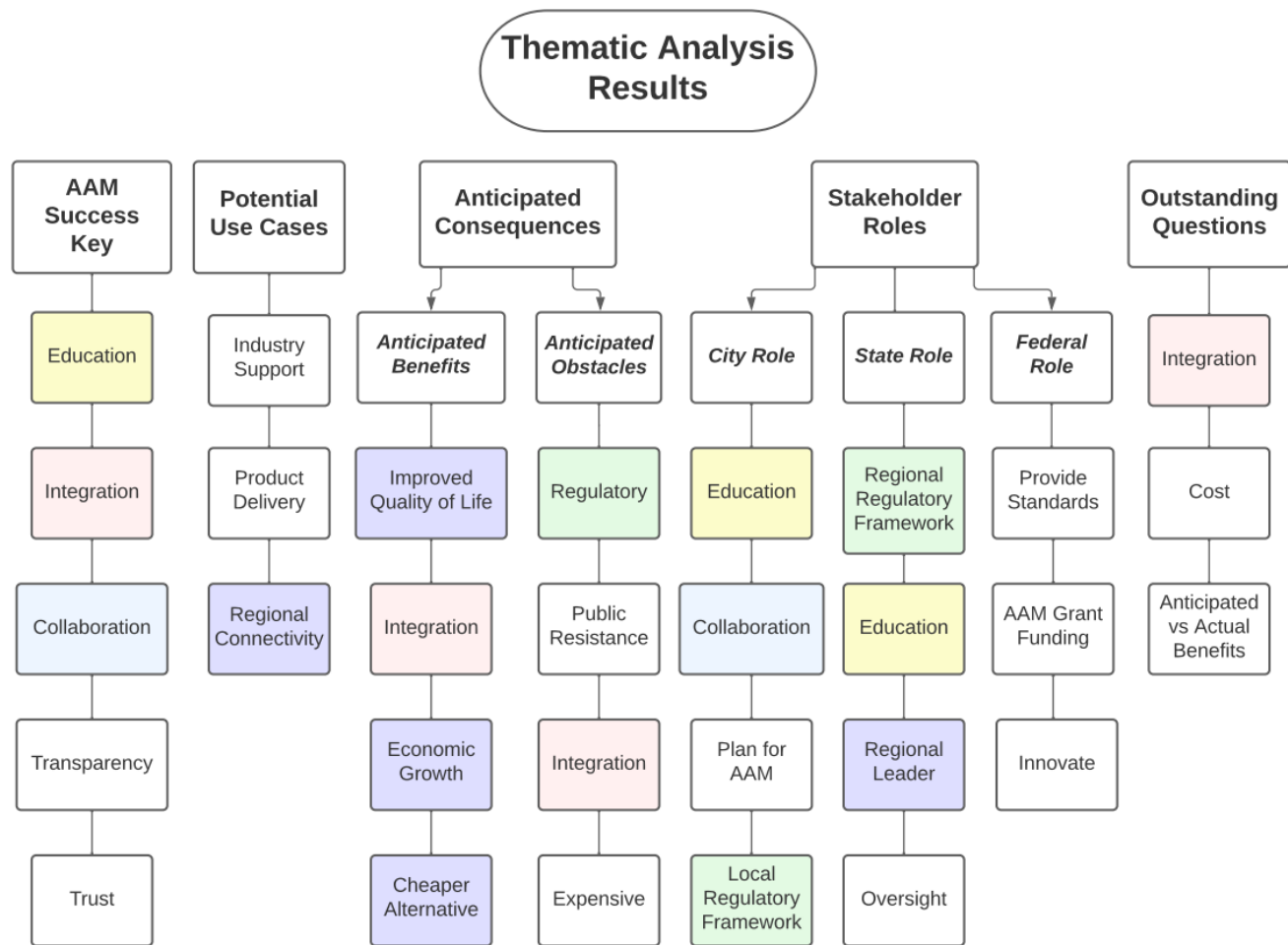


Figure 26: Thematic Analysis Results (Author)

4.2 AAM Success Key

While coding the transcripts it was noticed that frequently the various SMEs would say something to the effect of, “in order for AAM to be successful...” and then proceed to share thoughts on a range of things that need to happen or be considered to ensure the overall success of AAM. The code “AAM Success Key” was used any time that these ideas were expressed across the interviews.

Adopting the technologies of AAM, combining these new operations with traditional aviation in the National Airspace System, and integrating into local and regional transportation systems is no small task. The future of AAM is dependent on a multistep process across a vastly layered system of regulation and stakeholders; there will be many keys to its overall success, offered here are five guiding principles.

4.2.1 Education

The subject of education appeared in the dataset 114 times; of those 114 occurrences it was noted 63 times under AAM Success Key. Education is an overarching concept that is a sub-theme across three of the five themes. People can’t accept what they do not understand. From the policy makers to the planners to the general public, education is a key piece of the AAM puzzle. It is important to consider the following regarding AAM education:

- What does AAM education entail?
- Who should be educated and who should be doing the teaching?
- What are the best sources of AAM information?
- What is the best approach to AAM education?

4.2.1.1 What does AAM education entail?

AAM education entails understanding what AAM really is, what it is not, and what role it may play in society. In the current environment, a large part of AAM education is admitting the many unknowns and remaining questions, while still framing AAM in the proper context. One of the interviewed SMEs who will be known as respondent H, currently works within a public-private partnership

dedicated to enabling a comprehensive AAM outreach plan within one of the largest cities in the United States stated the following: “A lot of our work has been trying to undo what has been put out there around flying cars. The prospect of flying cars brings up a lot of immediate community concerns. So, what our work has been doing, is framing this back into aviation. This is not cars, this is aviation. These aircraft are using aerodynamic principles and using aviation infrastructure, so let's keep this in the realm of aviation.” Other SMEs agreed, an experienced city transportation planner working within a proactive east coast city to plan for AAM and who will be known as respondent B, expressed the need to convey the historic, rigorous safety aviation standards that new eVTOL will be held to. An employee at one of the leading OEMs, who will be known as respondent C said, “...to ensure people that these aircraft are safe and will be held to the same, if not higher standards as legacy aviation”.

For AAM to be framed into traditional aviation and compared to historic aviation safety records people would first need to understand aviation. Organizations likely use analogies around flying cars when attempting to explain AAM because it is something most people can relate to and understand. To explain AAM within the realms of aviation step one in AAM education is teaching about the history, the safety, and the impact of traditional aviation. Once people have basic understanding of the air transportation industry and can understand what AAM is and what it is not, then they can begin to understand the potential size and role of the emerging industry.

4.2.1.2 Who should be educated and who should be doing the teaching?

Ultimately the public as a whole will need to be educated on AAM but there is a timing component to a top-down approach to the eventual public engagement. State and city departments of transportation, state and city planners, and MPOs should be the first to learn about AAM. As these various entities engage with AAM and begin to incorporate it into their planning processes they can then educate policy makers at the state and local levels. When state or local jurisdictions are ready to proceed with steps towards integration of AAM the process will naturally lead to varying degrees of public engagement throughout the process. At that

point the leading stakeholders that were the first to be educated would then become educators.

State and local departments should seek their initial learning from the best available sources. Funding should be secured to hire an AAM Subject Matter Expert in a consulting role or as a full-time team member that can assist in the education piece. Departments can also fund for onsite or offsite training courses in which their staff can participate. In addition to hiring the services of a SME, departments can engage with various organizations who can play pivotal roles in learning about AAM.

4.2.1.3 What are the best sources of AAM information?

As the AAM industry continues to grow, as companies continue to go public, the articles and news coverings from the media also grow in frequency. While there is a place for these, these are not the best sources of information when engaging in an in-depth educational process to fully understand and prepare for AAM. The FAA and NASA continue to produce resources that are helpful in understanding the regulatory environment and national breadth and vision of these emerging technologies. The OEMs provide information not only about their aircraft but many of them have conducted surveys, studies, and outlined their goals for bringing aircraft to market to serve the public.

Universities around the world house researchers who are actively engaged in researching the many aspects of AAM, the academic community continues to offer valuable resources. Companies, small and large, are also offering not only written resources but consulting services from qualified SMEs. Organizations like Flight Crowd in the United Kingdom and the Community Air Mobility Initiative (CAMI) in the United States are platforms fostering key collaboration between experts, between industry and communities, and have various resources available to assist in understanding AAM.

4.2.1.4 What is the best approach to AAM education?

Suggestions of best practices for AAM education came through the interviewing exercise. It is important to respect the humanity within this process, both those

seeking understanding and those doing the educating. Respondent H, aSME specializing in AAM education stated, “There is a human component to all of this, with just listening and empathizing with folks to understand their concerns.” There are real concerns on both sides of the AAM argument and all parties involved should listen to understand. Where there is sincere listening, there can be true learning amongst all involved parties, for example, aviation planners should be open to learning from surface transportation planners and vice versa.

Timing is an important piece to this equation; the right people should be engaged at the right time. Respondent B, the transportation planner SME outlined their city strategy about timing, “the strategy we took which we found helpful was before we engage our broad audience, really engaging our local stakeholders like adjacent counties, adjacent cities, private companies that have an interest in this as well as our local transit operators.” It is important to first engage the other leading stakeholders and provide some baseline AAM education, provide context which leads to the start of productive conversations. This could also lead to cross-agency opportunities to combine funding to bring in an AAM SME to assist in understanding AAM as a whole, as well as at a local level.

Another common best practice from the data was the importance of starting early to meet people where they are in their understanding and then patiently giving them manageable doses of information. AAM education truly is a step-by-step process whereas those manageable pieces of information can be digested, then more productive conversations and higher levels of understanding can begin to be achieved. Technology can be a powerful educational tool, one of the SMEs working with countries arounds the world to understand AAM use cases and adoption, who will be known as respondent G, said the following regarding technology: “using a 3D visualization tool so that you can go onto a map of a city or onto a shade file for a city and design tunnels in space above the city and you can see them three dimensionally. It is a pretty powerful capability and tool to demonstrate the noise footprint of an electric vehicle flying at various altitudes and various speeds, etc. When you can colour the noise, the noisiest areas are red for example and the quieter areas are a shade of blue. But being able to show

how you can minimize the impact on communities of these environmental concerns is a big deal.”

It is in an AAM educators’ best interest to use the latest technology, tools, and data to properly explain what AAM entails. It is important to have an educational strategy that accounts for the proper stakeholders being engaged at the best time. Use the best available sources and engage with the experts from regulatory and industry organizations to assist in all educational efforts.

4.2.2 Integration

Integration: to form, coordinate, or blend into a functioning unified whole (Merriam-Webster, 2022). Integration is a loaded term when it comes to the integration of AAM because there are so many touch points to coordinate and blend into existing systems for it to ultimately function in a wholistic manner. Integration is another repeating sub-theme, occurring four times across the five themes. Integration will be discussed here through the viewpoint of it being an AAM Success Key and further explored from different perspectives within the other correlating themes.

There are multiple touch points of AAM integration, for example: airspace use, the Air Traffic Control system, the use of UTM, ground infrastructure including the electrical grid and green field vertiports, land use, transportation systems, regulatory, business models, the passenger interface and so many more. Each of these touch points is layered with potential obstacles and questions about the best approach to integration. While there is still much to be understood, there was a consensus across the interviewed experts that the ultimate sustainability of AAM relies on its eventual integration.

The FAA is known for their “crawl, walk, run” approach to AAM, and when it comes to integration this may be the best approach. As AAM stays framed properly within the greater air transportation industry, there is a framework in which integration can begin and be guided to higher levels of integration as AAM matures. Examples include using the existing regulations for aircraft certification and operational certification to allow these aircraft to begin operating using

existing traditional aviation infrastructure. While operations are enabled for AAM aircraft to be treated as any other aircraft within the NAS, it allows time for new regulations and standards to be established empowering the next phase of integration to begin across the many touch points.

Technology will permit higher levels of AAM operational frequency and therefore higher levels of integration. One of the SMEs, who will be known as respondent E, views this technology as a highly critical piece, he said: "...to deconflict traffic, maximize saturation in an airspace, and maximize throughput. That's going to be accomplished primarily because of the technology in the background that's doing that air traffic control piece. Because we get down to the numbers that we are talking about in AAM, are impossible on voice, they are going to have to be computer connected. And avoidance, deconfliction, scheduling, etc. it won't happen if we don't do that, if we don't have automation."

Often the industry feels that the present technology is held back by existing regulation. Continual collaboration between industry and regulators will expedite the creation of new regulation and therefore the adoption of new technologies. Stakeholders at all levels should work together to prepare for these initial phases of operation while also maintaining a holistic, long term view of integration.

4.2.3 Collaboration

Collaboration: to work jointly with others, to cooperate with an agency with which one is not immediately connected (Merriam-Webster, 2022). Collaboration was the second most frequent sub-theme across the entire dataset and repeatedly identified as an overarching key to the viability of AAM. By definition the aviation community needs to get out of the echo chamber and engage with industries, agencies, and communities that they may not be familiar with or normally do not work together.

The FAA should continue to lead the way by example by collaborating not only across the various internal departments but across governmental agencies and organizations. From the top down there should be open lines of communication where the FAA can work with all 50 states departments of transportation. In turn

each state DOT can openly communicate and collaborate with the regional MPOs, counties, and cities.

OEMs have led the way in collaboration while continuously announcing partnerships over the last few years. Many of the OEMs have partnered with automotive manufacturers, infrastructure and real estate companies, airlines, aircraft management companies, and many more. These partnerships are encouraging as it will take the expertise of multiple industries coming together with a similar vision for AAM to mature. While OEMs have done well collaborating with others, respondent C, the SME from a leading OEM, noted the following

“There is not a lot of industry collaboration. There are organizations out there like the General Aviation Manufacturers Association (GAMA) who are trying to bring the industry together, but from my standpoint there is still not a lot of collaboration or sharing of information between the companies. That is understandable, I get that. But if we are to make this a successful thing, we really should be working more closely together than not. Our company itself is at fault for that too, we want to keep things close to the vest, we want to be first to market, want to make sure that our technology succeeds over others. But I think from an industry perspective, for all of us to be successful we need to have more collaboration, to let that silo of ‘let’s not share anything and be super secretive’ should come down. We should be more openly collaborative because eventually this will be an equal system, we all will need to share and operate within.”

There is of course a balance to be found there considering proprietary information, but the main point is the need for far more industry collaboration. Rather than each OEM taking their own approach to an AAM system, industry should continue to work with regulators, communities, academia, and stakeholders to find paths to a holistic system.

4.2.4 Transparency

Transparency is to share thoughts or opinions honestly, initially this may seem to be an odd AAM Success Key, but the principle applies in a variety of ways. Half

of the interviewed experts expressed concerns about what is being promised around the capabilities of AAM. Respondent H said, “one of the biggest problems with AAM today is the media taking some of these concepts and anchoring what is possible on technology that does not exist yet.” AAM educators should not over promise on AAM capabilities and should educate using data driven sources. OEMs should be held to the same standard; all marketed benefits should be backed by realistic data.

While there are many anticipated benefits surrounding these new technologies, it is critical that all stakeholders do not only promote the good, but they must also be transparent about potential negative externalities. For example, one of the legacy aviation concerns is aircraft noise. New eVTOL aircraft are much quieter, and while there is promising data emerging about noise levels the fact remains there is still noise associated with the aircraft; messaging should never claim these aircraft are silent or will go unnoticed.

In order to build goodwill with the public or with the regulatory powers that be, it may be tempting for companies or organizations to withhold information or over focus on only the positives of AAM. This would not be genuine goodwill, because at some point the hard issues will surface and all of that groundwork building goodwill will be for not. Stakeholders must study to understand the potential negatives and concerns and should always seek to be completely transparent every step of the way. Transparency and honesty are key to the long-term success of the integration of AAM.

4.2.5 Trust

Trust and transparency are closely related success keys because it will take being completely transparent and honest to build relationships of trust. Lessons about public engagement, being transparent, and earning public trust can be learned from various industries, one example within traditional aviation is from the airports industry. Airports have a long history of addressing public’s concerns such as noise or pollution. One of the experts who participated in the study is a highly experienced airport operator and will be noted as respondent A. She said the following regarding trust, “Having those underlying relationships and trust of

your constituents is very important in order to be able to share a message and for it to be received.”

Just as with many of the other AAM success keys, laying a foundation of trust with the public at the federal, state, and local levels must be done in a slow and steady way. A large part of building the relationship of trust comes back to the human component discussed previously, the public will need to be heard and have their concerns validated and addressed. Communities want to have a say in establishing rules of operation for AAM in their direct area and how it impacts their lives. Interweaving these AAM success keys of education, collaboration, and transparency will create the necessary foundation of trust for the public to have the platform to express concerns and participate in AAM integration.

Stakeholders leading the AAM efforts such as state DOTs, MPOs, city and county transportation departments must lead by example. As these agencies collaborate with one another relationships based on transparency and trust need to be established. Each agency has their expertise to offer and should be heard, for instance, as the silo between transportation planning and aviation planning comes down, each should trust the other parties' expertise. The ultimate test of trust amongst stakeholders and especially a test of the public's trust will be if OEMs, operators, state, and cities can all deliver what was ultimately promised.

4.3 Potential Use Cases

Throughout the interviewing process many potential use cases within the realm of AAM were discussed. AAM was previously defined in the background and literature review sections as an umbrella term of a variety of emerging technologies. In the previous section regarding Small Unmanned Aircraft Systems, current use cases were largely explored. The majority of these current uses have yet to reach mass levels of acceptance or utility so were included as “potential” when the thematic analysis was completed. The potential use cases are truly diverse, but the top recurring uses from the dataset have been categorized into the following groups: Industry Support, Product Delivery, and Regional Connectivity.

4.3.1 Industry Support

Small Unmanned Aircraft are currently supporting many industries, examples that appeared in the dataset, many of which are repetitive from the previously mentioned section: industrial inspections, search and rescue, police use, wildfire management, communications surveillance, and airport compliance assistance. This is certainly not a comprehensive list of the many ways AAM can support existing industries.

An interesting example of how AAM could support an industry emerged from the data, which is the hospitality and tourism industry. Respondent B, who has done planning in a particular location where this concept was studied said, “One of the first scenarios probably being some of that hospitality/tourism sector because there tends to be a willingness to pay a higher premium for some of those experience-based activities...folks will be more likely to pay a little bit more for that type of experience while on a trip or on that special occasion.” The idea is that people would be willing to fly in an electric air taxi to the amusement park, resort, or event as part of the entire experience. If this demand does exist, then UAM certainly can play a supportive role to the entertainment and hospitality industries.

Another way AAM could play a support role was not necessarily for an industry but rather supporting cities’ equity efforts. Respondent A said, “I could foresee AAM supporting cities in their efforts...when you think about environmental justice needs...or to support engaging diverse populations in solving concerns around employment or medical treatment.” Many of the experts agreed that using AAM for the greater public good should be a guiding principle and would be instrumental in the overall acceptance and success of the industry. Each stakeholder should consistently ask how AAM can support greater equity of transportation, products, and services to all people.

4.3.2 Product Delivery

AAM is inclusive of small drones, large unmanned cargo aircraft, eVTOL aircraft or hybrid aircraft; the large variety of aircraft will be capable of transporting a large

variety of products. The SME from one of the 50 United States departments of transportation who will be known as respondent F thinks it will be an evolution from small package deliveries up to UAM air taxi operations. He said,

The reason I say it will probably see that progression is both from the FAA regulatory standpoint of what aircraft can we certificate? And then, once certificated, how fast can it be manufactured in mass? And then, how quickly can it be manufactured, sold, and put into operation? Drones can be manufactured quickly, DJI has already proven that. Nobody has proven that an air taxi can be manufactured quickly. That's why I see drones coming first, they can be manufactured quickly; they don't require an FAA certification for the vehicle itself. Although, they do require a Part 135 certification, which is easier to obtain.

Drone product delivery has been happening, an example of a scaled operation is Zipline who has delivered just shy of 2 million products using their drone delivery network (Zipline, 2022). Drone medical and food deliveries are expected to continue to grow, especially in rural areas. All of the large parcel delivery companies are actively engaged in using AAM technology to increase their service quality.

Just as new use cases continue to emerge as drone technology has matured, it is expected that additional use cases for AAM aircraft will become operational. One of the most common product deliveries mentioned in the interview was medical supplies. As discussed in the literature review sUAS aircraft have started to transport human organs, lifesaving blood, antivenom, vaccines, AEDs, and other medical products. As the larger AAM aircraft become certified and operational it would be reasonable to expect medivac service providers to adopt this new technology to transport injured people, move doctors and larger equipment to areas of need. Using AAM early on for medical deliveries and services will likely result in greater public understanding and acceptance that would build a foundation for it being used for other product deliveries and services.

4.3.3 Regional Connectivity

Respondent G, who has completed multiple location specific AAM market studies around the world said this concerning regional connectivity, "...with regional air mobility there needs to be a large urban area on at least one end." Although a brief statement, it is profound when it comes to where the market demand for AAM services will be, it is not so much between small rural towns, rather it is more about connecting outer regions to urban cores. Regional air mobility loosely being defined as 50 to 150 miles for a one-way trip.

As leading and planning stakeholders maintain a holistic view with the goal of integrating AAM into existing transportation networks then AAM can serve the unique needs where current transportation gaps have occurred. Increasing the capabilities of a transportation network will extend options to suburban and rural areas and provide the regional connectivity. It is anticipated that regional connectivity will provide a reliable, fast link to large and medium hub airports and to the urban centre for potential workforce commuting services.

In the suburban or rural areas infrastructure buildout could be easier and allow for the creating of strategic regional transportation hubs. AAM creating transportation hubs or connecting into existing transportation networks will provide more connectivity and travel options. This wholistic approach can enable public-private partnerships to foster economic development, job growth, and a more robust regional transportation network.

4.4 Anticipated Consequences

Anticipated Benefits and Anticipated Obstacles are two themes that came up frequently, for a combined total of 227 times across the dataset. These two themes were combined under the overarching term Anticipated Consequences. The consequences of AAM integration at this point are purely anticipated, organizations work hard to do studies and provide data that gives insight into what can be expected, but until the initial phases of operation nothing can be known for certain. These are also very subjective, for example, there are many opinions on both sides on whether something is actually going to be beneficial to

a community. In this section the top four predicted benefit sub-themes will be explored, these include Improved Quality of Life, Integration, Economic Growth, and Cheaper Alternative.

4.4.1 Improved Quality of Life

The most recurring anticipated benefit from the dataset if AAM is successfully integrated was improved quality of life. Upon evaluating the comments of the interviewees across this sub-theme, three categories were developed: healthcare, environmental, and connectivity.

AAM has the potential to increase healthcare services thus improving quality of life for communities. Respondent G said, “One of the most substantial social benefits will come down to areas like medivac, organ delivery, vaccines, testing, moving medical specialist to the location of the injured, things of that nature. The communities today accept very noisy medivac helicopters because they know that someone is in there that needs to be taken care of and so it is the exception.” If the technology provides quieter and more affordable aircraft that prove their capabilities over time it is expected that medivac and other medical delivery service providers would be early adopters.

Respondent A pointed out that with the invention of telemedicine the access to healthcare professionals has been greatly expanded but not necessarily the access to medications. In rural areas where people may not have immediate access to pharmacies, they may have to drive great distances or wait days to receive prescriptions in the mail. AAM can fill that gap left by telemedicine and could provide a rapid link to medications and other medical supplies. Again, Zipline has proven the benefits of such a network.

In addition to improved healthcare the argument was made by respondent F that large scale adoption of things like drone delivery could also lead to greater safety. He made the case of currently there are many UPS trucks, Amazon trucks, and FedEx trucks zipping around neighbourhoods with kids playing, but with a properly planned AAM delivery network, there is a potential increase to safety factor. It was also noted that by removing more of these delivery vehicles from

the road, it could lead to cleaner air, which improves health, but is a standalone category of anticipated environmental benefits.

AAM has the potential to tip the scales towards a greener, more sustainable, and environmentally friendly aviation option. OEMs are often quick to share how their all-electric aircraft is not burning traditional fuels and releasing harmful emissions into the atmosphere. While many of the study participants agree that AAM could be a step in the right direction on environmental efforts, there were several hesitations. Respondent H who is actively doing AAM community integration and policy work in one of the largest US cities said,

“With the emissions side of it, AAM, electric aviation, has the opportunity to eliminate that. There will still be number of traditional aircraft in the air because of the range restrictions with the current battery technology. (Creating) the perception that there will be immediate impacts to air quality associated with aviation through AAM is also misleading. As we have learned from surface side transportation planning, where there is capacity, there will be new demand. So instead of replacing trips that would otherwise be taken in a traditional aircraft, it is mainly just adding to the airspace. It is adding new aircraft to the airspace and to the whole system. It is a double-edged sword on that, yes we have the opportunity to reduce emissions but initially it is going to be just more aircraft overall.”

Respondent D expressed similar concerns about the increase of demand and whether AAM will truly be assisting environmentally.

“(The promise of) lower environmental impacts, where sure, if you are operating totally green electricity into this vehicle and you are not making any life cycle emissions. There are of course other types of emissions, in terms of battery development and disposal, and vehicle development. A key concern, whenever you give someone a faster, easier, lower paying way of traveling, they are going to increase Vehicle Miles Travelled (VMT)...if we are going to have people living farther out it is going to increase VMT. So, energy usage is going to potentially go way up as a

result of an AAM mode. That is not necessarily the right direction, that is not necessarily the more environmentally friendly.”

There is hope that AAM can improve air quality by reducing lane miles and reducing air pollution and be an environmentally responsible travel option. But while there is the hope, additional research needs to be conducted to understand the concerns around increased demand and increased VMT. Additional research can lead to more sustainable solutions allowing these environmental goals to be realized, thus increasing quality of life.

The last category within the expected improvements to quality of life is greater transportation connectivity and convenience. It is anticipated that if integrated into city and regional transportation hubs that AAM would provide a highly convenient, fast, affordable, and flexible transportation option. This would create an overall improved public transportation system for the greater good of communities. These key point to point connections could provide time savings, allowing more face-to-face connections, and enabling more discovery for more people.

A more capable transportation system inclusive of AAM may also provide a rapid link to people only when they need it. One of the interviewees explained this concept while comparing it to another form of current transportation, “Studies we have looked at, particularly with tolling lanes in the pacific northwest, lower income groups still make use of toll lanes, and they are willing to pay for that added convenience and for utility and value for their time when they need it.”

These levels of connectivity would provide people more choices of where to live, even rural living, while still being connected to the economic cores of cities. Those larger cities that properly integrate AAM could make the case that it would be a more favourable city to live within and attract more people to live there. The potential economic benefits of AAM and the connectivity it can provide will be further explained in a later section of anticipated benefits.

4.4.2 Integration

The second highest occurring sub-theme found under expected benefits was integration. Integration was introduced as an AAM Success Key and will be

discussed here through the lens of the anticipated benefits of AAM integration. As previously established the approach to AAM integration will be a phased application starting initially with existing aviation infrastructure. Primary AAM operations may utilize current small-hub or regional general aviation airports or in some areas, use heliports.

As federal regulations and standards allow the next stage may be the retrofitting of other existing infrastructures such as parking structures. Respondent E, an aviation ground infrastructure expert said the following about parking structures:

“(Many OEMs) are looking at parking garages. So, it is a low-tech thing that allows for high tech operations. It is an interesting mix. It is interesting because that is the lower tech side, it is usually overbuilt so it is able to go up another floor or two or three. It is open on all 4 sides, so you don't have the turbulence issues you have with standard buildings, most of the time the air goes through, instead of rolling up over the top. It is not an occupied structure, so it does not have living quarters or business underneath, so the fire code is much less restrictive.”

Other participants noted that the building of new vertiports and eVTOL infrastructure may be done first in rural areas where there may be less obstacles. Even with the potential obstacles of building vertiports in busy cities, the general agreement of the participants is that the ground infrastructure for AAM is less intrusive than traditional highways. Interviewee B stated “...linking key areas without having to invest a lot into ground infrastructure and additional lanes of highway or rail lines. It is a lot easier to put in two vertiports and connect two locations then it is to lay 30 miles of additional highway lanes.” So, the AAM ground infrastructure itself was considered a benefit within integration.

Integration will allow for the seamless adaptation of AAM aircraft not only into the existing aviation system but a new tool to support other transit options. If these visions of including AAM into a wholistic transportation network within cities can be realized these and other anticipated benefits could become a reality.

4.4.3 Economic Growth

It is predicted that AAM can bring cities and regions economic growth. Half of the interviewed experts mentioned the importance of involving the local economic development teams in the beginning discussions of AAM adoption. There are departments of economic development on the state and county/city level; these various departments should play a role in the development of a regional AAM vision. Respondent A shared what is happening in their city, “In our city, the economic development team has been sitting at the table with all of this as we bring entrepreneurs and innovators into town to discuss the technology. They are helping us identify funding strategies and recruitment strategies that will support our ability to recruit these new ideas and business to come to our area.”

Another expert emphasized the importance of early city engagement with local businesses around what AAM technology is and how it could potentially benefit their companies. These early conversations could lead to strategic public-private partnerships in standing up AAM within a region. In addition to dialogue with local businesses, the city should view this from a planning perspective and seek to understand how AAM can support the overall economic development plan. Respondent B, a city transportation planning expert, said the following in his interview:

“(We) are looking at vertiports as a part of a possible economic development strategy. So similar to sometimes you have economic development around a transit station because it becomes a hub of local trips coming in there, and then from that central point you go out and disperse and vice versa. So, we are looking at that as an opportunity as well to create those hubs of activity and economic development and closer into our central core than you would a traditional airport, again because it is a much smaller footprint.”

An underlying guiding principle that continually popped through the data in subtle ways is that idea of seeking to understand how AAM can support other goals of the city or region, in this example, the overall economic growth of an area. If cities and states start early and smartly plan to integrate AAM not only into the

transportation systems but into the fabric of how to improve the lives of their constituents, then perhaps they will be able to reap the benefits of economic growth.

4.4.4 Cheaper Alternative

The last of the anticipated benefits to be discussed from the analysis is how AAM may be a cheaper alternative. While there are studies about the expected passenger cost to use AAM, this section will discuss it more from an infrastructure and operations perspective. Due to the powerplant fuel approach of AAM aircraft being electric, hydrogen powered, or hybrid systems it is anticipated that these aircraft will have a much lower operating cost when compared to traditional aviation.

As mentioned within the most recent integration section the transportation planner believes the ground infrastructure needed to support AAM is a more affordable option over traditional roads or rail. Interviewee D agreed but made a valid point when he said, “The infrastructure itself, is not necessarily expensive, but the locations they want to put it are very expensive, they are often built up.”

Although real estate prices or retrofit costs of built-up cities could be a challenge the OEM expert believes the infrastructure will be capable of scaling up, respondent C noted:

“It really does not have a big footprint, if the city is successful in having one operation, the good thing about these things is it can be scaled up if they decide they want to build more vertiports. The cost to build a vertiport compared to another lane of highway or an airport is fractional. So, this is a much cheaper method of transportation because the infrastructure footprint is so much smaller than what you would need for another airport or another road to increase your traffic density.”

Although 100 percent of the participants struggled to see AAM as a mass transit option, there were thoughts about trying to scale operations to make it as affordable as possible. Participant G shared one way to do that would be using larger aircraft, he noted that for some of the business models to be viable a larger

aircraft capable of carrying 15 to 20 people would need to be used to bring the price point down. There continues to be research on how existing regional aircraft can be electrified or how these new AAM energy technologies can be scaled to larger aircraft.

Many sincere efforts are being made to fully integrate AAM in a way that results in a new cheaper alternative, creates economic growth, and can improve the quality of lives around the world. These bold and admirable efforts continue to be met with a variety of obstacles.

4.5 Anticipated Obstacles

The anticipated benefits are perhaps more subjective than the anticipated obstacles because many of the obstacles to AAM have already been engaged with countless people working to find solutions. In this section the top four sub-themes for expected obstacles will be discussed.

4.5.1 Regulatory

The top anticipated obstacle against AAM identified in this thematic analysis was predominately regulatory hurdles. The regulatory concerns expressed from the interviews and subsequent dataset were separated into five categories: FAA Concerns, Airspace, Certification, Infrastructure, and State and Local.

4.5.1.1 FAA Concerns

While a few of the interviewed experts praised the Federal Aviation Administration and their efforts towards enabling AAM technology, the majority of the SMEs expressed various concerns. One of the biggest concerns was about the FAA not viewing AAM holistically and being too focused on only AAM aircraft certification. Respondent F, one of the state directors of aviation expressed these concerns when they stated:

“The FAA deals with both aircraft and airport, but when it comes to AAM I only see them dealing with the aircraft; the sexy thing that the industry is chasing. That's what tells me that they're being forced to chase that part. But the land side part of it, the part that goes on the ground, that connected

touch point, they're not chasing that. They're not trying to solve those problems as quickly.”

The certification of various AAM aircraft is expected within the next two to three years, but the planning and building of AAM ground infrastructure may take significantly longer. The FAA will likely need to create new building and design standards for infrastructure, participant E, the ground infrastructure expert, expressed concern if they do these standards by the rule-making process, “if they do it by rule, that is a 6-year process on a good day. They should have started three years ago.” It was an 8-year process for Part 107 over sUAS to become regulation, the concerns about the seemingly lack of progress on infrastructure are understandable considering these lengthy processes.

Aside from how long the rulemaking process can be, respondent F expressed concerns regarding FAA administrative procedures and balancing those with safety. He said:

“It's an administrative issue with FAA at that point, I think it's the bureaucracy that's the biggest holdup now. To keep it safe they have to do it right, it has to meet the aviation standards that we've been accustomed to and should be accustomed to have 99.99% reliability rate. It must be that. I completely agree. But I think if we're going to innovate and innovate quickly, we can't let the industry drive government. Government needs to have an ambition of its own.”

The FAA does have a webpage dedicated to UAM and AAM where a few generic questions are answered and in June 2020 they released the UAM ConOps document. But there are concerns about how little the general industry knows about what the regulatory body is doing regarding AAM, two of the eight SMEs, noted they wish the FAA was more transparent of their efforts. To address some of these concerns and regulatory hurdles it is recommended that the FAA lead from the top with the identified AAM Success Keys of education, collaboration, transparency, and trust.

4.5.1.2 Airspace

Airspace is a large obstacle, because many of the business models rely on UAM operations within already complex and busy airspace near large-hub airports or within busy cities. As AAM operations begin they will be treated like any other traditional aviation operation. But to scale AAM operations the airspace design and management will need to adapt. Interviewee G expressed it this way:

“One of the biggest problems is not so much this year’s problem but certainly in the next 5 to 10 years and that is what is going to be done about airspace design? There will be a requirement about special equipment and systems. If you take heliports and vertiports in urban areas, you are going to need to use something much better than GPS to be able to navigate that vehicle to touch down. Especially if the vehicle is in close proximity to obstacles like buildings and all that sort of stuff. So, there are a lot of challenges to respect to the UTM infrastructure that have yet to be addressed.”

4.5.1.3 Certification

There are two types of certifications to be earned before getting to market, the aircraft itself must be certified and then a company must obtain an operational certificate. The OEMs are focused on first getting their aircraft certified, one challenging aspect of this was shared by the OEM SME, respondent C said, “It is hard to put up half a billion dollars for an aircraft when you have no assurances that the FAA will approve that aircraft for the operations that we envision.” The FAA is being forced into a new realm with all electric aircraft certification and are going to be very thorough and not give assurances too early in that process.

Once aircraft are certified there will be the operational certification, but another key challenge will be the mass production of the newly certified aircraft. Many of the OEMs have created strategic partnerships with automobile manufactures as referenced earlier, which will likely help with mass production. Getting high volumes of AAM aircraft into the market will be an important piece to bringing the overall price point down for consumers.

Within the FAA “crawl, walk, run” approach it is anticipated that the crawl phase will apply current regulations to AAM operations. When it comes to operational certification and holding AAM aircraft to existing regulations there are some concerns. Respondent C shares an example:

“Under current regulations they require up to 45 minutes reserve on an Instrument Flight Rules (IFR) flight, in addition to what is needed. If you apply that same regulation to an aircraft with a max range of 150 nautical miles of flight time, you can see how detrimental that could be to that aircraft. From a VFR standpoint, they may be able to operate under that but under IFR, those regulations, while they need to be complied with, it is really hard to extend your operations assuming your battery life stays around that same amount.”

Another example is that depending on aircraft certification Part 135 can require two pilots for commuter operations. This could negatively impact AAM business models. Another concern regarding pilots is the current pilot shortage. Depending on what the FAA ultimately requires of pilots to act as Pilot in Command (PIC) of AAM aircraft could either assist with the pilot shortage or exasperate that industry issue.

4.5.1.4 Infrastructure

The regulatory concern about infrastructure was discussed in regard to the FAA perhaps not devoting as much attention to it, but there are other regulatory issues related to AAM infrastructure. For AAM operations to properly scale and remain viable a robust AAM infrastructure is needed. But before that infrastructure can be planned and built a set of standards is needed. Before a set of standards can be fully developed the AAM aircraft performance data is needed. Respondent E, the aviation ground infrastructure expert who is assisting in the development of these standards noted the following about trying to get performance data:

“The FAA is trying to create something that is performance based for eVTOL and UAM. The problem that we are running into, is that we do not have the data to support that process. And when you ask, and we have

done several surveys with the manufacturers. We say, 'hey, here is 40 questions on performance' and I get these 41 responses that says, 'to be determined'. That is really hard to put into a formula..."

It is a very challenging environment where the order of current operations within the regulatory process is not necessarily matching the ideal order or timeline needed to provide infrastructure in conjunction with certified AAM aircraft beginning operations. The industry and cities and states are waiting not only on FAA AAM ground infrastructure standards but also many questions remain about what standards the International Code Council will release related to AAM infrastructure fire code, building code, electrical code, and more.

4.5.1.5 State and Local

The state and local regulatory roles will be discussed in greater detail within the Stakeholder Roles section, but when it comes to potential obstacles related to regulation at this level a few concerns came through the data. At the state, county, and city level there will be greater political involvement from elected officials. The personal bias of those elected civil servants around the role of government and the role of public transportation could greatly influence local AAM policy.

Participant F said this on the topic, "Like today we have flyover states, right? That's what we call them. Yeah, we will have fly over cities. Where some city mayors will say, 'yeah, let's go do this.' And some city mayors say, 'I don't know. Let me ask everybody.' And the loudest voices will win, and they will become a flyover city." Some cities or states are working to be proactive and avoid being an AAM "flyover city" these entities can work with state policy makers and local elected official to first understand what AAM is and begin those discussions.

Another local regulatory concern are the many issues that could appear in the planning, approval, permitting, and building processes of AAM infrastructure. Just as the creation of federal regulation is a time-consuming process, likewise at the local level these processes can take years. As AAM infrastructure works through local planning, zoning, public hearings, city council debates, voting, approval, permitting, building, and inspecting processes there is an array of regulatory

obstacles that could arise. One of perhaps the biggest expected obstacles is public resistance.

4.5.2 Public Resistance

There is a long history of public resistance or concern with traditional aviation, it is inevitable that there will be many public opinions with respect to AAM. Respondent H said it well when he said, “The things that excite aviation people about AAM really scares the average person.” The top anticipated public concerns from the dataset are:

- Safety – Are AAM aircraft safe? Will drones fall out of the sky onto people? What oversight will there be?
- Quality of Life – How loud will these aircraft be? What will the frequency be? Will it impact views or enjoyment of outdoor space? Will it impact private property values?
- Security/Privacy – How secure are AAM aircraft, can they be hacked? Will these aircraft be invading privacy? Will there be overreach with this technology?

People fear what they do not understand, using the top AAM Success Key of education will greatly help in meeting these concerns. While it will help, educating the public on AAM will be a significant obstacle in and of itself. As discussed in that education section, because the media has communicated AAM as flying cars, it is understandable people have concerns about safety. Because of the well-established high noise levels of traditional jets and helicopters it is also very reasonable that top concerns are about noise and quality of life concerns. The last top concern about privacy and security is also understandable, especially in the context of a recent refocus by many on individualism and freedom within American politics.

Another community concern will likely be about the equity of AAM. Interviewee H, the AAM community integration SME provided incredible insight on this issue:

“There is a gap in how the FAA thinks about equity and how communities think about equity. Communities are thinking about equity in regard to

protecting neighbourhoods and residents from negative externalities across all transportation modes. Making sure we are not levying all of these burdens onto one demographic. Really trying to protect communities and make sure that any new regulation or transportation mode that is being introduced that its benefits and its detriments are shared fairly. Whereas the FAA's take on equity surrounds this idea of access to the airspace and so that is mostly seen at public use airports with grant funding where those airports have to be open to any aircraft that is using the airspace.”

This fundamental different view of equity and how it may relate to AAM could be a profound issue and may lead to more public resistance towards AAM. The AAM Success Keys of collaboration and transparency will be helpful in addressing this issue.

Another way that transparency will be crucial is being open and realistic with the public about initial AAM operations. If OEMs or cities or states are not honest about it then it could lead to heavy public resistance. Interviewee D expressed concern about this issue,

“In the U.S., it will come down to, again, the actual nature of the service. If you are trying to do UAM passenger service in a taxi like atmosphere, if it is implemented and they just kind of build this big infrastructure and they do a lot of flights mostly for the wealthy people, then it might not be well adopted because it is not deemed accessible or useful to the average person and it is creating a lot of externalities.”

Other interviewed experts agreed and expect that due to the nature of UAM it will initially only be for individuals of higher net worth, that is until the aircraft production and frequency can rise, thus lowering the consumer cost. If UAM passenger operations are established too quickly or never reaches the level of frequency needed to make it accessible to the average person if that is what was initially promised to the public, then it could ruin public trust.

Throughout the lengthy process of local AAM integration there will be many public hearings for community members to voice their concerns. There will be loud

voices of pushback, it is important to properly engage with these opposers and to prepare for the worst. Respondent D was forward enough to bring up the “worst”:

“The big elephant in the room for any implementation is not if, but when the accident happens and where. You know, there will be problems and if something happens in a community, like we saw in New York in 1976 when the Pan Am building had an accident and it killed passengers and bystanders. If something like that happens, it could shut off a community, or it could shut off literally the whole country to these types of services and very much so sour the mood.”

Working with public concerns is something that will likely never go away, but hopefully is something that can be mitigated, especially when standing up initial AAM operations. Communities will want to see not only data but be able to see, hear, and feel AAM. Employing AAM Success Keys and industry best practices for community engagement will create public trust and the ability to overcome the highly anticipated obstacle of public resistance, at least to the degree necessary.

4.5.3 Integration

To meet integration efforts AAM must first demonstrate highly repeatable operations. Reaching a fully integrated AAM system across all the necessary touch points raises a host of issues. The depth and breadth of these potential setbacks is truly complex and will be difficult to overcome. While some of the more well-known integration touch points have been previously discussed in other sections, a few less thought about issues came through the dataset under this theme and sub-theme.

One of the experts referred to ground infrastructure as a “kingpin, or corner post of the entire AAM service”. While there is much that entities can do to properly plan and execute that plan for ground infrastructure, there are some current obstacles to certainly consider. Vertiport site selection may prove to be a bigger trial than one would initially think. Vertiport site selection should account for the

airspace, for the land use or zoning laws, the demand for service, restriction such as the power grid, integration ability with other modes of transportation, and more.

Another less discussed concern for AAM operators will be the reliability of accurate weather information. Figuring out microgrid weather data collection and reporting will be instrumental in the safe operations and at urban, suburban, and regional vertiports and of course the flight paths in between. These types of concerns or problems must be considered when creating plans for integration.

4.5.4 Expensive

While AAM infrastructure and AAM as a transportation mode was discussed as a cheaper alternative in the anticipated benefits section, the flip side shown through as one of the leading obstacles. Before discussing the customer perspective of cost, there were a couple of points from a systems-perspective. Participant G brought attention to the high cost of certain infrastructure, he said:

“There is potential for the ATC system in most countries to serve in low volume, eVTOL flights at low altitudes. But when the traffic begins to pick up, there will be the need for UTM in a very specific sense and that is all infrastructure, it is very expensive stuff. Our company has done a lot of work in the area, and we know, literally several billion dollars will be needed to build out those two infrastructure supply chains.”

Another systems concern that will be expensive to build deals with the limitations of the power grid to provide the charging support to all-electric eVTOL aircraft. Respondent E explained the following:

“We need to look at the electrical grid - its age, its capacity, and its room for expansion. And there are locations that have that because they are newer, there are locations that do not have any of that because they are so old. Those things will influence where do you put things because that is going to have a huge price tag to it. The average grid system has no capacity, so now you have to put in a substation, people hate substations with a passion! Then when you look at site location, say you do not have the power and you have to bring it in, so when you look at that base price

of moving electricity to a location, it is about a million dollars a mile for what we are talking about.”

With both of these infrastructure needs having high costs and long build times, it may be challenging to find investors willing to wait that long for a return on investment. Investors have been highly interested on putting money into AAM aircraft certification, but it may be more difficult to raise money for the non-exciting business case of necessary infrastructure.

For the AAM passenger perspective of cost, as noted before, the initial operations will be relatively expensive until frequency can increase to a point where the service cost can decrease. A few of the interviewed experts are sceptical if that price point will ever come down to be an everyday transportation option for your average person. Interviewee D was critical of some of the projections, he stated:

“Near term cost projections that are coming out of non-OEM sources, something like the NASA AAM study, are saying \$8 to \$9 a passenger mile for this type of service, that is very expensive, that is more on the range of a helicopter today. And then with the OEMs and even applying very aggressive scaling and cost factors you can get it down to \$2 or \$3 a passenger mile, I think that is still black car level. Some OEMs say, well we will get it down to 50 cents per passenger mile, which is the everyday person transportation. I have serious questions, again if that is realistic.”

While it has yet to be seen, one of the anticipated obstacles for the integration of AAM is the fact that from a passenger perspective and from a systems point of view it will be expensive.

4.6 Stakeholder Roles

For AAM to become an integrated mode of transportation it will take the collaboration and work of countless people and organizations. There are currently many stakeholders actively playing a role in the growth of AAM and the number will continue to increase as the industry matures and operations begin with certified aircraft. Within the scope of this research and in line with the original

research aim only the roles of the following stakeholders will be discussed: city, state, and federal.

Note: When the term “city” is used, it is largely referring to the city employees of the transportation and planning departments. When the term “state” is used, it is largely referring to the state department of transportation and/or division of aviation. When the term “federal” is used, it is largely referring to the Federal Aviation Administration.

4.6.1 City Role

Cities are an integral piece to the success of AAM adoption and have a large role to fulfil. Although organizations have begun working in this space to assist cities in understanding their AAM role, gaps in the current literature still stand. This research seeks to add to the literature by discussing the following top occurring sub-themes related to the city stakeholder role: education, collaboration, plan for AAM, and local regulatory framework.

4.6.1.1 Education

The first step a city should take when considering the integration of AAM into their transportation network is getting educated. The planning and transportation city departments should gain a thorough understanding of AAM at the start. Other city departments, neighbouring city or county agencies, various stakeholders, and eventually the public will look to these departments for answers and guidance. Before they can take on the role of teacher, they must seek education from the best available sources.

When considering this education component, there are three main stages of the process. Stage one should include a thorough search of online available resources. Becoming familiar with the studies and documents from the FAA, NASA, and other reliable sources. It is important to not rely on flashy news articles or marketing materials as the sole sources of AAM education. Respondent D noted the following:

“First is educating themselves, really taking the time and effort to understand what AAM is. I think that there are some organizations that

have done this really well, but in my opinion, most cities or large MPOs do not have a good handle on this. Where maybe they see a lot of the marketing materials and they read an article or two and then think that they have a good handle on it.”

AAM is full of complexity and in this initial stage of understanding it is unlikely that cities will come to a full understanding of everything, but they should seek to understand the overall concept of AAM operations. Seek to understand the role that AAM can play in general, but specifically start pondering the role of AAM in their city and region. This first stage of education helps a city gauge interest, if it is determined there is an interest then there should be some intermediate steps to prepare for the next stage of learning.

Those intermediate steps can include setting up an AAM planning committee, invite more people to the table, share what was learned in the initial phase and outline next steps. Secure funding to send staff members to AAM specific conferences and training. Hire an AAM expert to be on the team or have as a consultant. Reach out to the OEMs to express interest and seek their help. These steps will allow for the next stage to be highly productive.

With the help of Subject Matter Experts and the OEMs the next stage of education is doing an analysis to understand the complexities of AAM through the local lens. Participant D shared what this stage could look like:

“Once cities have done the education of their staff, the next thing is the matching of potential benefits or the identification of potential benefits for their region of responsibility, their jurisdiction. Doing the actual analysis of if we had this capability, where would we put it, how would it complement our current transportation portfolio, does it make sense for our jurisdiction or us in relation to other jurisdictions? I think there should be a lot more internal modelling by MPOs using their land-use transportation models, there should be a lot more discussion between neighbouring regions of would this help us? Do we want this? Is this more cost effective than building a light rail or adding another highway or do we even want to be more connected? Is that a good thing considering VMT and energy usage?

Should we just build a fiber line instead and have better connectivity digitally? In a dream world these would be the types of questions being asked in the analysis being done...”

Doing a thorough analysis, with the right people, asking the right questions will create a foundation of understanding. In addition to the points and questions outlined by the above quoted SME, below are a few other points of consideration from the dataset.

- Execute a market demand study for the region
- Seek to understand city dynamics, land use, zoning, demand, airspace use, etc. when planning vertiport sites
- View AAM holistically and seek to understand potential community benefits and the negative externalities

Although this actionable item falls under city role, it is important to note that although one city may take a leading role, this process should include neighbouring jurisdictions. Participant B, the transportation planner SME working for a proactive AAM city said,

“We took a multi-step approach with our stakeholders, including and really getting adjacent communities involved, we may be leading this AAM plan...but it is a regional effort. Flying vehicles do not care if they are flying over political boundaries so having that broad based, local, or regional approach when really starting with that education component is key.”

Once initial learning has taken place and an in-depth regional analysis has been done then the third stage of the education process is to educate others. Once city planning departments have data from the analysis, and a general plan concerning AAM adoption then they can prepare to educate the regulatory powers, the political leadership. As explained within the AAM Success Key section it is important to involve the right groups at the right time. Interviewee B weighed in on these points, he said:

“The strategy we took which we found helpful was before we engage our broad audience, really engaging our local stakeholders like adjacent

counties, adjacent cities, private companies that have an interest in this as well as our local transit operators. Reaching out to them to set the stage so we can have that discussion with the powers - the regulatory powers - those that have that direct impact in terms of policies, procedures in transit. Because if we just went out and said, 'hey what do you think of this' without giving any kind of background or a good understanding of what this is then you can't even have that conversation, it is too new and too unknown to a lot of people for them to have useful conversation without having that background knowledge."

When the stage is set and departments begin educating the policy makers it should be done in manageable bits of data, providing time for them to digest the information and engage in meaningful ways. Once city servants have an understanding of AAM and its possible role in their jurisdictions, the plan may be start moving forward through the various regulatory processes, which will create the opportunity for public comment. Just as with the teaching of the political powers, the public will need to be educated to be empowered to provide productive feedback.

Cities will need to have a public engagement plan which may include having a city AAM plan website, hosting open houses, and doing other community outreach. These platforms can be used to educate the public on AAM, present the regional analysis data, share the plan, and then seek citizen input. It is critical to follow the principles outlined in the AAM Success Key section concerning transparency. Being transparent with the public about not only the anticipated benefits but also the unknowns and anticipated negative externalities.

Community engagement will never truly be completed, it will be an ongoing stage of the education process. Cities should be patient and while they continually make information available and seek to educate the public on these topics, it will be important to remember the human component. Cities should listen to the concerns of the public, empathize with the concerns, and then work collaboratively to address the concerns.

4.6.1.2 Collaboration

Collaboration was one of the top AAM Success Keys and is something a city will want to be proactive about. Aviation planners and AAM advocates will not be able to do this on their own, and if they try to do so, they will be seen as competition. Respondent H shared the following:

“We are trying to improve the transportation system, trying to improve cities overall by improving the transportation system and within any given city there are many other government organizations, transit authorities, and transportation advocacy groups that are all working on the same goal (of improving the transportation system). And by not forming joint goals and agreed upon goals across the board by everybody who is working on transportation we then start looking like competitors.”

Early on I noticed this with the transit agencies; transit agencies saw AAM as a threat and potential competition, similar to what ridesharing did. So, the knee jerk reaction to that is to try and discredit it and try to work against what some of the AAM advocates are trying to do to make it happen. All that work is delaying progress towards this more integrative and wholistic approach, so we need to start breaking out of our silos and having discussions with all of these other agencies who are also trying to improve transportation systems and improve cities overall.”

All the interviewed experts agreed on the need for multi-department, multi-agency collaboration and some expressed concern about how difficult that may be. The state representative noted how engrained the roles of the transportation planning has been. Respondent F said, “You’ve always had the airport planners, the urban planners, and the highway planners. The highway planners and the urban planners work well together. And when it comes to airports, they’re their own guys, they do their own thing. We don’t even talk to them. So, they are pretty siloed.” This is a silo that will need to be broken down, true collaboration must be fostered between these highly critical players.

Different planning groups each have expertise that are necessary for the success of AAM helping improve transportation systems. Urban planners, land-use planners, transit planners, aviation planners, economic development planners, environmental planners, and more all have key knowledge and roles to play. In addition to the planning agencies, many organizations, advocacy groups, layers of government, various industries, and communities must work together towards the wholistic integration of AAM.

4.6.1.3 Plan for AAM

Cities who take on the roles outlined within the education and collaboration sections will simultaneously be developing a plan for AAM. Considerations were discussed within the education section regarding the local analysis, but below is a list of additional action items a city should examine when developing an AAM plan:

- Identify viable markets, identify routes that will be beneficial and bring value to the city
- Plan vertiport locations from a transportation network systems perspective
- Identify vertiport locations along chosen routes accounting for land-use plans, zoning, current airspace, and community factors
- Consider balancing demand and equity to AAM services
- Identify funding strategies
- Organize a methodical stakeholder engagement plan

Respondent A advised cities to think broadly when starting to create an AAM plan, she said, “cities need to be thinking on the larger scale about all of the various opportunities versus a narrow view of potential uses.” Maintain the broad view and include AAM and how it could potentially help in the long-term city planning discussions.

4.6.1.4 Local Regulatory Framework

Once a city has a plan for AAM adoption, action can be taken by policy leaders to create a local regulatory framework to enable that plan. Rather than pursuing

exemptions from current local regulations or laws, cities should seek to pave the way for adoption in a way that is repeatable and flexible. At times it may be difficult to know where to start because the path to integration is unknown but think about what can be done today. Respondent H, an expert working on AAM integration in a large US city said,

“What we have been trying to do in my work is focus on, with the long-term goal of integration in mind, what can we do today and what can we do tomorrow? What can we do when the first aircraft are certified in 2024? That is why it is so important for all levels of government to start doing early policy work to understand that our goal is integration but making sure we do not get too ahead of ourselves and focus too heavily on technology that does not exist yet.”

That early policy work on a city level could be taking the completed analysis and planned vertiport site locations and as the land-use regulator adjust the zoning ordinances as needed to properly zone the land for future AAM ground infrastructure. As these zoning ordinances pass it is important for cities to have the AAM terminology and taxonomy of the terms properly defined and in place. Cities can explore what local regulations can be passed that would be welcoming of AAM. Interviewee E said, “What is going to be the biggest thing that a municipality can do is start thinking about what those policies and ordinances are going to look like to be a friendly community towards this new transportation model.”

Cities have standard protocols for the conditional use permitting process to allow for zoning exceptions. Similar to how these protocols are in place, a city should think about creating a checklist and process that can be in place as a baseline. By having a framework foundation ready it will be easier to adopt proven standards as they come out around vertiport infrastructure, building code, fire code, and other standards. Proactive cities who are doing this early policy work can be instrumental in collaborating with the federal and state stakeholders to carve out a regulatory path forward for AAM.

4.6.2 State Role

Each state of the 50 United States of America has a Department of Transportation, each of these departments of transportation has some version of a division of aviation or aeronautics. Each state has a state aviation system plan that is maintained by their respective aeronautics divisions. Although these divisions and system plans may vary slightly from state to state, the general purpose of these entities is to promote, grow, and manage air transportation on a state level. Each state has a significant role to play in the regional planning and integration of AAM, the data sub-themes include regional regulatory framework, education, regional leader, and oversight.

4.6.2.1 Regional Regulatory Framework

The state is already a regulator in the aviation environment. States often oversee the Federal Airport Improvement Program (AIP) grant money that comes into the state to fund airport projects. States often have their own aviation infrastructure funding mechanism and to ensure the protection of aviation assets have inspection programs to oversee the proper use of federal and state funds. In this regulator role, the state can take the lead and provide guidance as cities look to create a regulatory framework for AAM. The state can ensure what is planned, developed, and eventually operated on a local level is viable and useful across the state transportation system.

The state should be participating in much of the same planning efforts as described for cities. States should consider the policies that need to be in place to enable to adoption of AAM. As these policies are developed, they should be anchored in the FAA definition of AAM, respondent H explained:

“The FAA definition of AAM, which is problematic, even the FAA has acknowledged it has its short comings, but where we are creating policy and trying to anchor that policy on something that is represented or accepted across different levels of government...once you start developing policy or regulation you need to be anchored to something as official as it can get”

The majority of AAM routes will cross over multiple jurisdictions, although cities have a big role to play, the state should be there to lead the regional aspects of AAM. The state should be working to develop the regulatory framework that can lead to the long-term vision of AAM integrated regional transportation.

4.6.2.2 Education

The state role concerning education has its similarities to the city's role with education, but it also has some key differences. State divisions of aviation must educate their staff on AAM technology and the many complexities of AAM integration. States should secure funding to become thoroughly educated and to bring SMEs onto their team. They should do all that they can to establish themselves as the regional expert because cities, counties, MPOs and others will turn to the state for help on their own educational efforts. The state should provide educational materials and forums to foster collaboration and educational opportunities.

State transportation departments and their aviation teams should be collaborating with their federal agency counterparts, working with cities throughout their state, and remaining highly informed. These efforts will allow state aviation officials to properly brief and educate the state governor, legislative body, and other regulatory powers on the opportunities of AAM technologies. Interviewee A said this is the top role of the state, she noted, "The top role of the aviation director is for advocacy at the capitol." This educational component and legislative advocacy will be key in making progress on any state level regulation concerning AAM.

4.6.2.3 Regional Leader

Counties and municipalities will look to the state division of aeronautics to be the regional leader, as respondent A said, "to spearhead the state-wide efforts of AAM". Many cities will not be able to do this on their own, they simply don't have the current bandwidth necessary. Participant B, the city transportation planner SME, explained this issue:

“From a time perspective for other agencies...they have limited resources and a lot of agencies don't have the staff, they are already understaffed. So, they have to ask themselves, ‘do we have time and effort to put this together?’ Looking at those organizations that do have set aside resources to make these planning efforts is going to be really important because a lot of communities may not have those resources. So that has been the reality more so than a negative attitude of ‘oh this is never going to happen.’ There is a burst of, ‘oh this is cool’ quickly followed by the reality of focusing on what they need to get done today and off of their desks today.”

States should be a regional leader by bolstering their own resources where possible to help cities. They can create opportunities for multi-jurisdiction collaboration, fostering these relationships can lead to the formalization of a coalition of agencies to pull resources together. AAM truly is a regional mode of transportation, and the state should take the leading role by doing early economic impact studies and market analysis studies. They should share the studies data and resources with cities that play a role in the state-wide transportation plan, and together establish what AAM looks like and feels like in their region.

4.6.2.4 Oversight

The FAA has oversight over public-use aviation infrastructure and current regulations allow the state to oversee any private-use aviation facilities. Previously mentioned the state is the middleman between the Federal AIP funding and the airports themselves on new construction projects, equipment purchases, and infrastructure improvements. Interviewee H explained why that is important, he said, “Most of the funding that comes from the FAA passes through state aeronautic departments to prioritize how we look at it from a systematic level, across the state. How is the state putting money in the right places to make sure the system is functioning as a whole? That role will continue to be important.” What that looks like considering AAM funding remains unanswered, but the state has traditionally played that role and may continue to have that oversight concerning AAM infrastructure.

States can create their own oversight and tie it to state funding opportunities. Respondent E explained how this could relate to AAM infrastructure, he said, “A lot of states protect their investments by having their own inspection programs for licensing and certification programs to receive funding through the state. That provides a model to make sure that we are also providing safe AAM infrastructure as well.”

Respondent F, the state director from one of the 50 United States views their role as comprehensive. He said,

“The role of the state is kind of be the mini-FAA, right? To do the aerial corridor planning, to do vertiport design planning, and to do vertiport location planning. To do the aerial traffic operation centre planning. To figure out the power grid requirements for vertiports and electric capabilities needed. The state level role is comprehensive. The only thing we don't do is design the vehicle, but, yes, the state role is truly comprehensive.”

This extensive state role will allow the state DOTs and divisions of aviation to be regional leaders and enable them various levels of oversight necessary to ensure a systematic and safe integration of AAM.

4.6.3 Federal Role

The federal role largely represents the role of the Federal Aviation Administration. Many different aspects of the FAA role have been intermingled in various sections, but three sub-themes that came through the data regarding the topic were: provide standards, AAM grant funding, and innovate.

4.6.3.1 Provide Standards

The FAA is the head aviation regulator within the United States, their mission is to “provide the safest, most efficient aerospace system in the world” (Federal Aviation Administration, 2022). They provide the standards and regulations across the entire air transportation ecosystem, overseeing aircraft, air traffic, airports, pilots, unmanned aircraft, and space. These regulations are published in the form of Federal Aviation Regulations (FARs) within the Code of Federal

Regulations (CFRs). Other standards are provided in the form of Advisory Circulars (ACs), Airworthiness Directives (ADs), orders, notices and grant assurances.

Regarding AAM it is expected that initially the FAA will work within existing regulations as much as possible. Where necessary the FAA will create new regulations, standards, and guidance. Through the research aim lens states and cities particularly wait for new direction concerning AAM ground infrastructure. On March 1, 2022, the FAA took a significant step towards providing vertiport standards, they announced Draft Engineering Brief (EB) 105 Vertiport Design (Federal Aviation Administration, 2022b). This FAA EB is to serve as the interim guidance for the design of new vertiports and modification of current aviation infrastructure to allow for eVTOL operations until a more comprehensive Advisory Circular can be published (“Engineering Brief No. 105, Vertiport Design”, 2022). The FAA will need to fulfil their role as regulator and continue to provide standards and regulations enabling the adoption of AAM.

4.6.3.2 AAM Grant Funding

From the beginning of the air transportation industry in the United States the federal government as provided various forms of funding to support the industry. In the early days of airlines, it was through air mail subsidies, when the Airline Deregulation Act of 1978 passed the Essential Air Service (EAS) program began (Wensveen, 2015). According to the US Department of Transportation website, “the EAS program was put into place to guarantee that small communities that were served by certificated air carriers before airline deregulation maintain a minimal level of scheduled air service” (U.S. Department of Transportation, 2017). EAS is still in use today on routes throughout the United States.

Three of the eight interviewed subject matter experts think that in order to stand up AAM operations for a larger amount of people that the federal government should provide route subsidies. These route subsidies could be defined and managed through a program similar to how they do so through the EAS program. Interviewee C, the OEM expert spoke of this in more general terms and said, “Maybe the FAA or the government will help supplement these, provide some

type of tax benefit that makes it beneficial for us to want to engage in smaller communities for the profit and not be as favourable as a major metropolitan area. In other words, how does the government make this attractive for us to want to pursue the smaller, underdeveloped areas?”.

The Airport Improvement Program (AIP) is the funding mechanism for airport infrastructure. This program is for public-use airports that are included in the National Plan of Integrated Airport Systems (NPIAS) (Federal Aviation Administration, 2021b). The FAA determines which airports are included in the NPIAS; this current infrastructure federal funding arm will fall short on how to fund public-use AAM infrastructure. Another option for funding that could be explored is the use of the Passenger Facility Charge (PFC), which is also in use at airports. Fifty percent of the interviewees believe the FAA has a role to play in funding the infrastructure necessary for an AAM inclusive system.

4.6.3.3 Innovate

Participant F said, “If we're going to innovate and innovate quickly, we can't let the industry drive government. Government has to have an ambition of its own. Right now, they are not doing that.” Other experts agreed but gave more credit, respondent A said, “The FAA is a very bureaucratic institution, and they are that way for safety reasons. They have a great track record of protecting the flying public. We have seen some strides made recently with space exploration regulations and so it will be exciting to see equal strides to be made with AAM.”

Interviewee C also complimented the FAA when he said, “To the FAA's credit, they have done a good job of really trying to work outside of their existing framework and be innovative to allow us to move forward with this aircraft development.” The FAA must find the balance of maintaining their established safety records while not stifling the innovative progress of AAM technologies.

4.6.4 Outstanding Questions

A common understanding among the interviewees and those engaged throughout the AAM industry is the understanding that when one question is explored, it typically unveils several more questions. While many questions

remain outstanding concerning the implementation of AAM technologies, the three sub-themes of this section to be discussed are: integration, cost, and anticipated versus actual benefits.

4.6.4.1 Integration

The topic of integration appeared as a sub-theme in four of the five themes and was explored from those various perspectives. Below is a list of the questions regarding integration that came from the dataset:

- What is the best approach to integrate high volume AAM operations into the airspace?
- What are the capabilities of UTM systems?
- What will the frequency of AAM operations be? How will high volume operations be sequenced?
- What about non-standard days, traditional aviation using holding techniques, but if AAM operations are using limited battery life how will non-standard events impact sequencing?
- As other modes of transportation move toward all-electric means will the power grid be capable of supporting electric cars, busses, scooters, bikes, on top of AAM aircraft?
- Fuel flowage fees are a main source of revenue at airports, how will that revenue be replaced concerning AAM electric operations?
- How will AAM impact travel patterns within a city? How will it impact community housing?
- What negative externalities will be a result of AAM integration 20 years post-adoption?

It is important to note that this list of questions is far from an all-inclusive list of inquiries concerning AAM integration. Rather it is a list of outstanding questions raised by the Subject Matter Experts who participated in this study.

4.6.4.2 Cost

Although there are studies and predictions on the topic of cost, it is perhaps one of the biggest unknowns until AAM aircraft enter service and actual operational data can be provided. Below is a list of AAM cost related questions:

- What will the customer cost for AAM transportation be?
- Is everyday use of AAM for the common person achievable?
- Will AAM be a cost-effective means for daily commuting?
- With the recent increase of remote work using virtual platforms, is the cost of AAM worth it?
- Will AAM infrastructure be public or private use? How will it be funded?

4.6.4.3 Anticipated Benefits vs Actual Benefits

There are many anticipated benefits of AAM such as the ones previously discussed: improved quality of life through better healthcare services, environmental gains, more connectivity, a more robust integrated transportation system, economic growth, and cheaper alternatives. But the question remains are these anticipated benefits actual benefits in the sense of are each of these things truly good for society? Will AAM really be able to accomplish these hoped for benefits? As AAM starts to become a reality in areas around the world, stakeholders should continually compare the anticipated benefits against the actual benefits.

4.6.5 Big Wins

As AAM technology matures and if all the obstacles can be overcome to reach a safe and fully incorporated transportation system across the many touch points of AAM integration, then there will be some big wins for society. These big wins identified in the thematic analysis are colour coded light purple on Figure 26 in Section 4.1. The overarching successes would be greater regional connectivity, improved quality of life, economic growth, cheaper transportation infrastructure alternative, and AAM states or cities becoming regional leaders.

5 Conclusion and Discussion

5.1 Reflection of Research Objectives

This thesis has made a literary contribution by having completed a thorough literature review of five main pillars of Advanced Air Mobility. It also created a literary framework to the many obstacles that the AAM industry currently faces. This work developed and executed a robust thematic analysis leading to industry relevant findings which contribute to a general framework of next steps for various stakeholders at this critical time in the AAM industry. Listed below are the original research objectives (RO) and a reflection of the findings.

RO 1: Understand the current state of the literature and contribute to the literature gap on AAM community integration

A thorough understanding was reached regarding the current state of the literature concerning Advanced Air Mobility. This understanding was a snapshot in time as the AAM industry is so quickly evolving resulting in the fast-advancing field of AAM research and academic contributions. This research adds to the present literature by providing a comprehensive overview of five of the main factors or sub-industries under the larger AAM umbrella: Small Unmanned Aerial Systems, Large Unmanned Cargo Aircraft, Electric Aviation, Regional Air Mobility and Urban Air Mobility.

The literature review created a detailed literary map shown as Figure 1 in Section 2.1 of the obstacles that need to be overcome for a successful integration of AAM into the transportation systems of cities, states, and countries around the world. The thematic analysis led to the identification of stakeholder roles, next steps, keys for success, and anticipated consequences. This created a general roadmap to provide utility to cities and states in the current environment of working towards AAM adoption. This thesis contributes to the literature gap around community integration of these emerging technologies.

RO 2: Identify local stakeholder roles concerning integration of AAM

The thematic analysis was successful in identifying key stakeholder roles, namely the roles of cities, state aviation departments, and federal agencies. It is important to note that these three stakeholders are only a small sampling of the many stakeholders that will play key roles in the adoption of AAM. Table 2 includes a summary of recommendations identified in the research and their correlating section reference, that the stakeholders can consider:

Stakeholder	Stakeholder Recommendations	Section Reference
City Role	<ul style="list-style-type: none"> • Invest in the education of the planning and transportation departments • Seek AAM education from the best available published sources and SMEs • Establish an AAM Committee on a city or regional level • Engage with the OEMs • Secure funding for a collaborative regional analysis • Execute regional analysis to understand local benefits, externalities, the demand, and future infrastructure sites for AAM • Maintain a holistic view of integrating AAM into the transportation system • Foster collaboration across city departments and neighbouring jurisdictions • Engage in early policy work to create a local regulatory path forward 	<p>Section 4.2.1 and Section 4.6.1.1</p> <p>Section 4.2.1.2 and Section 4.6.1.1</p> <p>Section 4.2.1.3</p> <p>Section 4.6.1.2</p> <p>Section 4.6.1.3</p> <p>Section 4.2.2</p> <p>Section 4.6.1.2</p> <p>Section 4.6.1.4</p>
State Role	<ul style="list-style-type: none"> • Invest in AAM education to become the regional leader • Serve as the regional leader in providing education, resources, and funding to cities striving for AAM adoption • Serve as the AAM policy advocate to state lawmakers • Advocate at the federal level for AAM funding sources • Provide oversight in a systematical regional adoption of AAM 	<p>Section 4.6.2.2</p> <p>Section 4.6.2.2</p> <p>Section 4.6.2.3</p> <p>Section 4.6.2.2</p> <p>Section 4.6.2.4</p>
Federal Role	<ul style="list-style-type: none"> • Ensure safety standards are met across AAM implementation • Provide AAM infrastructure standards • Identify federal funding programs to stand-up AAM • Continue to innovate and enable AAM technologies 	<p>Section 4.6.3.1</p> <p>Section 4.6.3.1</p> <p>Section 4.6.3.2</p> <p>Section 4.6.3.3</p>

Table 2: Stakeholder Recommendations (Author)

RO 3: Identify the keys necessary to successfully integrate AAM into local transportation systems

This work met this research objective and identified five AAM success keys including: education, integration, collaboration, transparency, and trust. Each of these were thoroughly discussed in Section 4.2, here is a discussion of the top points. Education is the top success key which includes understanding AAM, its role, and although it should remain framed in aviation knowing how it can supplement transportation as a whole. Cities, states, and MPOs should invest to learn about AAM from the best available sources and then in turn educate the various stakeholders and public.

The goal of complete integration into the NAS and transportation systems should be a focus throughout the process of adoption. Stakeholders should consider the many touchpoints across a successful integration of AAM in an effort to not compete but to complement the existing transportation networks. Collaboration will be key to integration and overall, as a success key. The FAA can lead the collaborative efforts by increasing the cross-departmental work to establish the AAM industry. Stakeholders should continually seek ways to break out of their echo chambers and foster meaningful collaboration.

Transparency is another instrumental principle for the viability of AAM adoption. Stakeholders across the AAM environment need to be open and honest about what AAM capabilities are at this current time and not over promise on immature technology. The anticipated benefits of AAM should never be one sided, rather the anticipated negative externalities should always be included in discussions, especially with the public. The AAM success key of trust is closely related and should be another guiding principle as stakeholders build relationships of trust and authenticity which will lead to a more honest integration of AAM.

RO 4: Identify potential use cases and anticipated consequences of AAM

Potential AAM use cases were discovered through the thematic analysis and discussed in Section 4.3 Expected consequences also emerged from the data and were evaluated in Section 4.4 The three potential use cases are more

generalized categories of utility, including industry support, product delivery, and regional connectivity. Just as sUAS have been adopted as a powerful tool in many different industries, AAM technologies will be able to support a large variety of industries. AAM technologies have the potential to increase the efficiency of product and cargo deliveries. New eVTOL and eCTOL aircraft can serve new markets increasing regional connectivity.

These and other use cases coupled with an integration of AAM will lead to potential benefits such as improved quality of life, integration, economic growth, and a cheaper alternative. Improved quality of life through better healthcare and emergency response, especially in rural areas as AAM can be used to better serve these communities. The potential to decrease harmful CO₂ emissions over time if the electricity comes from a green production source. Another anticipated improvement to quality of life is a more robust transportation system with another option providing greater connectivity and convenience.

Integration can lead to a seamless adoption of AAM technologies and serve as a good alternative when considering transportation infrastructure. It is anticipated that connecting areas via vertiports will be a cheaper option over traditional road or rail infrastructure. This is expected to create economic growth by connecting CBDs, stimulating job growth, and the ability of AAM to support economic recruitment of new companies.

To realize these discussed benefits and others there are several anticipated obstacles to be overcome. The identified obstacles from the thematic analysis include regulatory, public resistance, integration, and how expensive it may truly be. The industry is concerned that the FAA may be too focused on the aircraft development and certification rather than providing equal attention to a regulatory path forward across the board for AAM. For example, focusing on policy work to enable infrastructure for airspace such as UTM and then also AAM ground infrastructure. States and local cities will also have a role to play in regulation where there may be a variety of obstacles.

High levels of public resistance of AAM are highly probable as the public has concerns about the safety of AAM, how it may negatively impact their quality of

life, and apprehensions around security and privacy. There also continues to be uncertainty about the cost of using AAM transportation and the unknown of if it will be reasonable to use it in many of the OEM proposed use cases. Perhaps the largest obstacle is integration itself, the depth and breadth of full AAM integration is truly complex.

5.2 Limitations and Future Research

This research project started with broad aspirations; the current state of the AAM industry and field of research is quite extensive, there is so much work that can be done under the wide topic area. These current characteristics of the field of research, the face of AAM having such a large scope is by its very nature a limiting factor. Consequently, the scope of this thesis was refined over time and lays a solid basis for future research projects.

One constraint of this research was the limited sample size of eight Subject Matter Experts. While it was a limited sample size, the SMEs who did participate were highly qualified and are heavily involved on the national and global stages of AAM. Through the interviews with these individuals and the robust thematic analysis a strong foundation was established. This foundation can provide structure for future mixed method approaches using a large-scale quantitative survey and/or more in-depth qualitative studies with larger sample sizes of various stakeholders and experts.

This thesis met the original research objectives and accomplished the overall aim to provide a general road map of next steps that can be valuable to planners and policy makers on the local and state levels. This work has also produced a framework of challenges, each of which need a deep dive look for plausible solutions. This general framework opens the opportunity to proceed with additional in-depth work with the identified stakeholder groups to identify the details for the next phase towards AAM integration.

Not only the aviation industry but the transportation industry as a whole currently hold a valuable opportunity to work together in creating the better future of tomorrow. Evidence shows tremendous progress being made in overcoming the

technical obstacles, but without true community integration the technical advancements will be for not. Now is the time to embrace the keys for AAM success, for all stakeholders to collaborate in overcoming the identified obstacles, in a united effort to create a more reliable, more connected, and more sustainable transportation system for humanity.

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APPENDICES

Appendix A Interview Questions

1. How do you define Advanced Air Mobility?
2. How do you define Urban Air Mobility?
3. What do you think will be the first use cases for AAM?
4. Who do you think will be the early adopters for AAM?
5. How do you define AAM integration?
6. What do you think the timeline for AAM integration is?
7. What do you think is the biggest bottleneck of progress right now?
 - a. What specific obstacles do they predict and how should industry and regulatory work together to solve these big issues?
8. What are the anticipated benefits of UAM to a community?
9. When you hear the term “community integration of AAM” what comes to your mind?
10. What are the best approaches for community engagement?
11. What role if any should state transportation departments play?
12. What role, if any, should local cities and communities play?
 - a. Perhaps follow up questions about regional planning councils, city planning, public engagement, city politics, etc.?
13. Do you anticipate UAM being a mass transit option or more for personal travel for high-net-worth individuals?
14. Do you think UAM will be met with a lot of public resistance? Why?
 - a. How can we as an industry prepare to meet their concerns?
15. What needs to happen to ensure the equity of AAM technologies?
16. What do you think can be done in industry to break down silos and begin additional collaboration?
 - a. What other industries should the aviation/AAM industry be working with?

Appendix B Participant Consent Form

Informed Consent

-Confidential-

Title of the project:	Creating a Framework for Community Integration of Urban Air Mobility
Name of the researcher:	Aaron Organ
Researcher's contact details:	a.organ@cranfield.ac.uk or 1.480.254.9100
Participant number:	(for future contact and anonymity)
Date:	

Consent to participate and right to withdraw

1. I confirm that I have been informed about this research project and I agree to take part.
2. I understand that all personal information I provide will be treated with confidence and **my name** will **not** be used in any report, publication, or presentation.
3. I have been provided with a participant number as shown above. The researcher(s) will record data against my participant number instead of recording my name. The file linking my name to my participant number will be accessible only to the main researchers and will be securely destroyed one year after successful completion of the thesis.
4. I understand that I can withdraw from this project at any stage by informing a member of the research team, for whom contact details have been provided. I also understand that I **can withdraw my data** for a period of up to **7 days**

from today, as after this time it will not be possible to identify my individual data from the aggregated results as explained in point 3.

Security of data storage

5. I understand that the data I provide will be used by Cranfield University for the purpose of research. The data will be stored on the University's network that can only be accessed by authorised users, in line with UK Data Protection Act 2018.

Datasets

6. Interviews will be **recorded** and securely stored on the Cranfield University network as a recorded video file including audio. These files will be securely deleted as soon as they are no longer required.
7. The recordings will be **transcribed and saved** as .docx or .xlsx files. These files (and any backups) will also be securely deleted as soon as they are no longer required.
8. I understand that I have two options: one where my personal details will not be used at all and therefore any quote(s) extracted from my interview will be cited as **anonymised** transcript(s) or a second option whereby a reference to my professional role may be made but only in **pseudo-anonymised** transcript(s) i.e., created by removing or replacing identifiers such as name, age, and location. Both anonymised and pseudo-anonymised transcripts may be quoted from or published in support of findings (e.g. in journal articles, conference papers) as detailed hereinabove. Analytical software may be used to aggregate the results of the research and every reasonable step will be taken to (pseudo-)anonymise the data accordingly.
9. This research is being conducted with approval from the **Cranfield University Research Ethics System (CURES)** with Reference **CURES/12385/2020**. You can find more at the [Research Integrity Website](#) or by directly contacting the research supervisor Keith Mason at k.mason@cranfield.ac.uk if:

- You have questions or concerns the researcher cannot answer
- You have questions about your rights as a research participant
- You have any complaints with (about) the research(er)

Please Indicate Your Choice

☐ I consent for my anonymised transcript(s) to be published

OR

☐ I consent for my pseudo-anonymised transcript(s) to be published

Confirm and Sign

☐ I understand that the aggregated data will be published in support of the research findings.

☐ I have read and understood the terms and the information provided on this form.

☐ I give my consent to taking part in this research on the terms opted in above.

I confirm that I have read and understand the information provided on this form and give my consent to taking part in this research.

Participant's signature:		Date:	
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