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Emergent Themes of Operational Safety at Urban Air Mobility at Vertiports: The Stakeholder Perspective

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Emergent Themes of Operational Safety of Urban Air Mobility at Vertiports: The Stakeholder Perspective

By

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Abstract

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The emerging urban air mobility (UAM) industry is dynamic, complex, and still highly conceptual, as vertiports are not currently an operational reality in the United States. The UAM vertiport is at the epicenter of the emerging advanced aviation ecosystem, representing significant operating costs of approximately $130 million per year and more than that to design, develop, and implement. In addition to setting up and operating capital, there are considerable challenges relating to the safe design, development location, and operation of UAM vertiports, representing the confluence of human and autonomous systems, whose interdependence is not yet fully understood. UAM vertiport stakeholders are at the forefront of these significant challenges. However, until this research, there was little understanding of how stakeholders perceived and approached the associated problem-solving and decision-making. These data supported answers to the research questions asked of the purposefully sampled homogenous group through a semi-structured personal interview. The instrument was designed and tested with the help of independent UAM vertiport subject matter experts, and coding was developed using three independent coders to minimize bias, support code reliability, and add to the robustness of the findings. This study examines these stakeholders' perspectives, representing valuable intuition reflections, opinions, and decisions to understand vertiport stakeholders' perceptions, which may save considerable time in post-implementation fixes, more efficiently apply resources, inspire more within-industry trust, foster a much-needed UAM safety culture, and support human-centric safety and risk frameworks. Further, the findings of this study build upon the body of knowledge to support system integration, reduce human error, and increase operational safety.

The study's methodology was qualitative, non-experimental exploratory research through the plurality of narrative and phenomenological perspectives. The study used a strategically sequenced four-phase research design, a dynamic non-linear process supporting central core principles of collaboration, criticality, reflexivity, and rigor. The central value proposition of this study was the categorization of the qualitative codes and subcodes, leading to the discovery of three emergent themes: *within-industry trust, cultural friction*, and *fear of unknown risk*. The findings of this study appear to support human perspectives and opinions that determine behaviors, decisions, and outcomes currently influencing the makeup of the emerging aviation ecosystem and the future UAM vertiport system. Additionally, these findings provide valuable insight into *how* and *why* these themes influence the potential operational safety at UAM vertiports and the emerging culture of the advanced aviation landscape.
Keywords: urban air mobility, vertiport, stakeholder, perceptions, qualitative research, phenomenology, system-wide trust, safety culture

Dedication

This study is dedicated to my loving family, in particular my friend, Thomas L. Knode. Your patience and love enabled this amazing journey. To my family, especially my Dad, the late Dr. Bruce Lamb, your legacy inspired my journey; I know you would have been proud. My Mom, Sister, and Brother never fail to stare at me with blank looks but cheer me on anyway; your support and understanding for many missed family events have meant the world to me.

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Finally, I acknowledge and thank the study’s participants who gave their time to volunteer for the personal interviews. While you remain anonymous, your contribution was the central value tenet of this study, and your contribution will help us understand the challenging elements involved in building vertiports’ safety systems for the future of urban air mobility.

This study would not have been possible without the volunteer efforts of specialized urban air mobility and aviation subject matter experts and my volunteer independent coders. Therefore, I acknowledge and thank them here:

Subject Matter Experts:

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Dr. Barbara Holder, Ph.D., Embry-Riddle Aeronautical University.

Mr. Jonathan Daniels, Fellow American Society for Testing and Materials, Helicopter Association, Vertical Flight Society Working Group Leader.

Ms. Liza Josias, Eve Urban Air Mobility.

Independent Coders:

Dr. Danita Baghdasarin, Ph.D., Boeing Aircraft Co.

Dr. Andrew Koch, Ph.D., Naval Warfare Department.

Dr. Des Silagy, Ph.D., Federal Aviation Administration.

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Chapter I: Introduction

This first chapter introduces the concept of Urban Air Mobility (UAM), a subset of the emerging advanced aviation mobility (AAM) industry. The UAM industry encompasses the idea of *autonomous air taxis* taking the shape of small personal-sized aircraft that can take off and land vertically, often powered by electric propulsion and referred to as electric vertical takeoff and landing (eVTOL) aircraft. This new era of urban air mobility promises ordinary people affordable, safe, and accessible urban air transit from the convenience of rooftops, car parks, and other community areas (Federal Aviation Administration [FAA], 2020a, 2020b; Goyal et al., 2018; National Academies of Science, Engineering, and Medicine [NASEM], 2020; Rajendran & Zack, 2019; Rajendran et al., 2021). Further, this chapter introduces the central problem: a lack of understanding and formal identification of emergent themes associated with operational safety around vertiports. Next, this chapter discusses the study's objectives in the purpose section, followed by the potential significance, research questions, limitations, and delimitations. Finally, the chapter concludes with a concise summary to prepare the reader for the literature review in the next chapter.

Background and Overview

The background and context for this study are confined to the emerging UAM industry, and particularly the individual UAM stakeholders at the forefront of the industry-wide problem-solving effort. These UAM vertiport stakeholders aim to achieve the promised safe operations at UAM vertiports mentioned in the established industry literature and promoted to the communities that would potentially host them. These UAM stakeholders are individuals who work for organizations; for example, those who work for the civil aviation regulator, the aircraft manufacturers, and those in academia designing the systems, to name just a few (FAA, 2020a, 2020b; NASEM, 2020; Northeast UAS Airspace Integration Research Alliance [NUAIR], 2020, 2021a, 2021b). A deeper description of the UAM stakeholders is provided in Chapter III.

Significant problems and challenges are standing in the way of these UAM vertiport stakeholders; the reality is that in 2023, they only exist as theoretical and conceptual propositions, and there are very few real-life working prototypes, and none of these in commercial operations (Filippone & Barakos, 2020; Patterson et al., 2018). Furthermore, any simulations or controlled scenarios have focused on individual aircraft, usually small uncrewed aircraft or traditional crewed helicopters, systems tested and assessed in isolation rather than as part of the UAM ecosystem (Clothier et al., 2015b; FAA, 2020b; Hill et al., 2020; Pérez-Castán et al., 2020; Weibel & Hansman, 2004). As a result, stakeholder organizations and their people have yet to access a fully integrated working commercial vertiport.

The *UAM ecosystem* represents many interdependent components that need integration; for example, the variety of UAM aircraft, the airspace procedures and structure of the National Air Space (NAS) system, the take-off and landing areas (vertiports), and the environments and communities that host the vertiports. Other UAM ecosystem components include organizations such as the civil aviation regulator, private and public companies that provide navigation services and weather information, and the humans working within each element of this ecosystem. Although extant studies have focused on aspects of the UAM ecosystem, most concentrate on UAM components separately, and even fewer studies examine the UAM ecosystem through the lens of stakeholders facing the direct challenges of integrating these components. At the epicenter of the UAM ecosystem is the vertiport; it will be the focal point of arrival and departure for many UAM aircraft, passengers, refueling, maintenance activities, passenger catering, security, drone delivery, and scheduling. UAM stakeholders and the specialists who work for them have many challenges in achieving operational safety at vertiports.

In addition to logistical challenges, UAM vertiports represent the confluence of human and autonomous systems whose interdependence is not yet fully understood (Filippone & Barakos, 2020; NUAIR, 2020, 2021a, 2021b; Stouffer et al., 2020; Stouffer et al., 2021). Significant known challenges and barriers to UAM implementation relate directly to safety, public acceptance, certification, and regulations, and at the epicenter of UAM operations is the UAM aerodrome, or vertiport (Goyal et al., 2018; National Aeronautics and Space Administration [NASA], 2020a, 2020b; NUAIR, 2020, 2021a, 2021b; Patterson et al., 2021; Price et al., 2020; Reiche et al., 2019; Rice et al., 2020; Winter et al., 2020). A UAM aerodrome is often described within the literature as a vertiport; however, other terms such as vertiplace, vertihub, vertistop, skyport, and even the term *ventilates* were mentioned once in NUAIR (2020).

As of July 2022, there were no published regulations, very little formal guidance, or specific UAM vertiport standards to guide stakeholders in developing their vertiport safety and risk plans to support safe operations. However, in March 2022, the FAA released a draft of the vertiport engineering brief #105 to assist UAM vertiport stakeholders and their organizations, the Federal Aviation Administration. (2021b, September 8). However, the final Vertiport Advisory Circular was not due to be published until late 2023, and even then, information was primarily focused on the physical design and characteristics of the vertiport, rather than performance standards for aircraft or flight paths. Additionally, as many advanced aircraft and vertiports are still in the test phase, automated systems safety performance and actual capabilities and design preferences for operations at UAM vertiports remain unknown (Fillipone & Barakos, 2021; McSwain et al., 2020; Sarsfield, 2019).

In general terms, UAM stakeholders also include future passengers and people who live in the communities near the proposed vertiports and those who work in the buildings upon which a vertiport is planned to be located. However, for the scope of this research, the literature states that UAM stakeholders include organizations that directly or indirectly have a responsibility and accountability role in vertiport designs, implementation, regulations, safety systems, and public interest (NUAIR, 2020, 2021a, 2021b). Within these stakeholder organizations, the individual's roles and responsibilities are significant. Yet, there is little understanding or explanation of *how* and *why* stakeholders perceive the challenges of safe operations at vertiports and how their perspectives shape their approach and decisions in solving challenges. As an example, Koumoutsidi & Polydoropoulou (2022) conducted a qualitative survey study asking open and closed-ended questions of UAM stakeholders, focusing on gaining insights and challenges relating to the broader UAM industry by gathering data and conducting a SWOT [strengths, weaknesses, opportunities, and threats] analysis. As of July 2022, the literature review reveals that no identified study has asked: *What are these stakeholders thinking, why and how are they approaching these challenges, and what are their thought processes? How are these influencing their perceptions and behaviors?*

As they relate to a specific topic, the human factors of perception, reflection, and opinions must be examined to find emergent themes. These perceptions, reflections, and opinions often determine behaviors, decisions, and interactions in the world and within particular communities (Freire, 1973; Heidegger, 2005; Higginbottom & Liamputtong, 2015). These UAM vertiport stakeholders make functional design and safety decisions that may influence and direct future vertiport system interactions, which may also impact the design of security, safety, passenger and worker ingress, exit, and the ease of movement and access to and from the flight operations platform and aircraft at the vertiport. Therefore, this study explored emergent themes associated with these individuals' perspectives to uncover clues to support safer systems and processes. Thus, with the discovery of the emergent themes regarding the integration of operational safety at UAM vertiports, system designers, investors, and safety experts may be able to change their approach to decision-making within the advanced aviation industry, adjust, re-design, or implement safety precautions before real-world vertiport operations commence. Therefore, timely examination and consideration of intelligent stakeholders' perspectives may save substantial capital, support more efficient partnerships and collaborations, and save time in UAM vertiport post-implementation re-design, re-configurations, and system fixes prior to the expense of implementation (NASEM, 2018, 2020; U.S Government Accountability Office, 2022).

Statement of the Problem

The emerging UAM ecosystem is complex. It is also highly conceptual and theoretical, yet to become a reality. Understanding and solving challenges relating to the safe operation of vertiports that do not yet exist represents the confluence of highly complex human and autonomous systems that are not yet tangible or demonstrated in an operational environment. Additionally, technology is outpacing regulations, standards, and the human capacity to fully understand and solve the conceptual UAM ecosystem's challenges. As discussed in the opening of the chapter, the humans at the forefront of this industry-wide problem-solving effort work for UAM stakeholder organizations.

Therefore, a deep understanding of their opinions, perspectives, behavior, and decision-making is of critical importance, especially concerning the safe integration of safety systems and risk management plans (such as how the automation will handle aircraft movements, impacts of local weather and aircraft vortices' on aircraft sequencing and flight paths transitional lift characteristics) which may be vital to the initial success of the industry (NASEM, 2018, 2020; U.S Government Accountability Office, 2022). The problem is that there is little understanding of how and why stakeholders perceive the challenges of safe operations at vertiports and how their collective and integrated perspectives shape their approach and decisions in solving safety challenges. The challenge is compounded by the lack of systematic themes or frameworks for UAM in general and, specifically, safe, efficient operations at UAM vertiports. This gap in the literature represents a risk that operational safety assumptions by decision-makers may be incomplete or inadequate.

The literature indicates that the initial investment costs in a vertiport infrastructure are estimated to be approximately $35 to $45 million, with annual operating costs between $110 million and $130 million per year (Johnston et al., 2020). UAM vertiport stakeholders are at the forefront of designing and developing vertiport safety systems; if safety assumptions are misaligned or not understood, there may also be a significant financial risk. Despite this level of investment into vertiports and the key individuals working to establish them, no studies currently examine these individuals' perceptions, reflections, or opinions, particularly as they relate to collective emergent themes, such as intellectual intuition or hunches and safety and system assumptions. It is vital to gain an understanding of these perceptions, reflections, and opinions, as these drive the decisions and actions of the stakeholders, which will directly impact the localities, infrastructure, design, facilities, and training of operations at the UAM vertiports. Additionally, these factors will shape the regulatory and standards landscape and impact not only the business model of the vertiport but also the supporting business that will be needed for safe and efficient operations.

Purpose Statement

There were two main objectives for this study. The first objective was to discover and explore emergent themes relating to UAM vertiport operational safety from the stakeholders' perspectives, targeted at three specific UAM stakeholder categories: (a) academia and research and development, (b) the federal government, and (c) aircraft component manufacturers. These three stakeholder groups include organizations with a direct or indirect role and responsibility in UAM and vertiports in the United States, and that responsibility flows to the individual roles within the stakeholder organizations. A deep understanding of the perceptions, reflections, and opinions of the individual UAM stakeholders' experiences is required to identify emergent themes. Dialogic engagement through a personal interview was used to draw out and identify these emergent themes. This research addresses the central research question, and inductive lines of inquiry are learning the (a) how, (b) why, and (c) what of the stakeholders' experience, their perceptions, reflections, and opinions to understand their perspectives.

The second objective of the research was to outline a powerful inductive repeatable study with the purpose: to provide a robust, repeatable qualitative design and a foundational platform upon which to build quantitative contextual variables for further investigation. Drawing out emergent themes from human perceptions, reflections, and opinions in prior studies has been used to solve societal problems associated with racism, academic and school student engagement challenges, and issues with both civil and political engagement (Rappa & Jamil, 2020).

This purpose is relevant to the emergent UAM industry as this method has not yet been applied to UAM vertiport stakeholders and their challenges at the time of this project. It offers potential benefits that are expanded upon under the significance of the study. Additionally, this research fills the existing literature gap and contributes to the body of knowledge in the advanced aviation UAM Vertiport industry and contributes new knowledge regarding the influences of trust and the effect of negative emotions on a collective industry culture in this emerging advanced aviation industry.

Significance of the Study

Theoretical Foundation and Significance

Inductive qualitative research, especially from the phenomenological perspective, often relies on foundational literature and principles to build the conceptual framework that underpins the study. The conceptual framework cultivates the central research questions, methods, analytical tools, and instrument design (Creswell & Creswell, 2018; Higginbottom & Liamputtong, 2015; Ravitch & Carl, 2016). As emergent themes were not yet identified, this study began without a formal *theory of UAM stakeholder perceptions*; therefore, a collection of established foundational literature formed the required conceptual framework (Creswell & Creswell, 2018; Ravitch & Carl, 2016). Most notably, the foundational literature includes studies from the NASA Aeronautics Research Institute (NARI), which is considered the nexus of research into UAM, where independent research efforts contribute to the NARI research database available through their portal. This collection of literature was also the pivotal source for the purposeful sampling technique, assisting in establishing the criteria for selecting suitable participants.

The conceptual framework for this study was built upon the foundational literature generated by the NARI UAM stakeholders' working groups. In the foundational literature, UAM Challenges were presented as five critical challenge pillars and 24 barriers to implementation; seven of these barriers were overlapping as well as being interdependent (NASA, 2020a; Patterson, 2021; Price et al., 2020;). UAM stakeholders' roles and responsibilities are significant, yet there was little understanding or explanation of how and why stakeholders perceive challenges and how these challenges shape their problem-solving efforts. Therefore, the central tenet and potential for theoretical significance was the human phenomenological perspective, focusing on perceptions, reflections, and opinions, which often determine decisions and interactions in the world and within our communities (Freire, 1973; Heidegger, 2005; Higginbottom & Liamputtong, 2015). Subsequently, it was the data gathered from the interviews would be rich and thick with context and support the discovery of emotional factors and sentiment in addition to a comprehensive code hierarchy leading to the emergent themes that may hold the clues to better, safer systems and processes (Freire, 1973; Heidegger, 2005; Higginbottom & Liamputtong, 2015).

Practical Significance. Discovering emergent themes may add tangible value and help the UAM Vertiport industry by (a) pointing to potential risks that may not be part of mainstream conversations or be prominent in the literature or working group activities, (b) increasing cross-stakeholder relations (for example, between industry and government), (c) improving safety and risk management approaches, (d) possibly support economic efficiencies, and, finally, (e) may provide the regulators and government agencies new ways to consider regulations that influence UAM vertiport stakeholders.

Potential Beneficiaries. When considering the beneficiaries of the possible findings, it should be noted that UAM vertiport stakeholder organizations are diverse and either directly or indirectly responsible, accountable, consulted, and informed about UAM vertiport operations (NUAIR, 2021a). Therefore, in addition to the decision-makers and designers, additional beneficiaries of this research may be the passengers who will eventually enjoy safer, more efficient operations from UAM vertiports.

Research Questions

The current study explores the following research questions:

Overarching Research Question:

RQ1. What are the emergent or unknown themes relating to stakeholders' perceptions, experiences, and opinions of operational safety at UAM vertiports?

Supporting Research Questions:

RQ2. What are the UAM vertiport stakeholders experiencing at the forefront of the industry-wide problem-solving challenge?

RQ3. How are the UAM vertiport stakeholders experiencing being at the forefront of the industry-wide problem-solving challenge?

RQ4. How do UAM stakeholders' roles and responsibilities contribute to the safety efforts of the UAM ecosystem?

RQ5. How do these UAM stakeholders perceive their peers (stakeholders at other companies or organizations) experiencing problem-solving?

RQ6. How likely are interactions with other UAM stakeholder peers likely to influence the participant's opinions on the design of safety processes, assumptions, and systems?

Delimitations

Delimitations of this study investigated the perspectives, opinions, and experiences of UAM vertiport stakeholders in the United States. Like many qualitative studies that investigate a particular phenomenon experienced by a specific group of specialized individuals at a certain point in time, this study was delimited to the purposefully selected individuals of interest who were able to volunteer their time. Additionally, the research period was limited to a relatively short data-gathering period from the fall to the spring of 2022 and 2023. This period represented the timeframe where the emergent UAM vertiport concept was still largely conceptual, and only a couple of sparsely located vertiport prototypes have been described in the literature, including by Volocopter, a German AAM company, which is developing a prototype of vertiports and using the terms voloports and skyports; these are being built in Germany, Singapore, and Australia and are planned for full operation by early 2023 (Alcock, 2020; NUAIR, 2021b; Sarsfield, 2019). The fidelity of these vertiport prototype designs and performance-supporting characteristics are protected by the few organizations that would be operating from them. Therefore, these few conceptual prototypes were inaccessible to the broader community of UAM Vertiport stakeholders involved in the industry-wide problem-solving efforts.

Limitations and Assumptions

It was recognized during the design of the study that a central limitation or characteristic of qualitative research is the researchers themselves. It is widely accepted in qualitative research that the researcher is a foremost consideration, often described as the primary instrument, which can be a critical value proposition or be detrimental to the findings (Creswell & Creswell, 2018; Ravitch & Carl, 2016). For example, the researcher's *positionality* (role or position during the study), experience and qualifications, and even personality and gender contribute to a factor of a researcher's *intersectionality* (Ravitch & Carl, 2016). The combination of these amounts to the attributes of the researcher that could arguably contribute to bias; however, some argue that the researcher's attributes are necessary to add to the quality of the findings and to draw a meaningful understanding of the data (Bazeley, 2013; Ravitch & Carl, 2016).

Several accepted strategies were used to minimize the potential for researcher bias in this study: (a) robust design, (a) critical reflexivity, (c) transparent methodology processes for reliability and validity, and (d) stringent record keeping. To that end, reflexivity in the researcher's understanding was captured and summarized in the final chapter of this dissertation. Additionally, this research design utilized independent scholars and subject matter experts to shape the instrument's design and build the code hierarchy. These strategies were detailed in Chapter III and within the master researcher's log (MRL). The MRL was an electronic notebook containing high-fidelity notes supporting study replication and qualitative generalizability.

Additionally, most research relies on the assumption that participants will be earnest and truthful in their responses and participate faithfully in the task in the personal interview. In addition, the dialogic engagement with the volunteer subject matter experts to establish the instrument's validity is also assumed to be trustworthy and consistent with the faithful execution of the purpose of the study. The assumption and expectation of human factors such as bias and social desirability may emerge from the interactions and dialogic engagement with subject-matter experts.

Summary

This chapter presented the reader with the background and context of this research project as it applies to UAM vertiport operational safety from the perspective of the UAM stakeholder. The rigorous inductive inquiry aimed to draw on the highly contextual participant transcripts that supported coding of their opinions, perspectives, emotions, and how they were experiencing being at the forefront of integrating with UAM vertiport operations. UAM vertiport stakeholders' experiences support the new knowledge and the emergent themes, which will, in the future, help categorize highly contextual quantitative variables and factors for future research. In addition, this chapter introduced the reader to the complexity of the advanced aviation ecosystem and how the UAM vertiport is the critical focus point for advanced aviation to operate within communities.

Further, this chapter pointed to the importance of understanding the people involved in the systems as the human actors at the center of the industry-wide problem-solving effort relating to designing and implementing safe operations of UAM vertiports that are yet to be in commercial operation. Understanding UAM stakeholders’ perspectives on this topic, which includes the elements of (a) perceptions, (b) reflections, and (c) opinions of individuals at the forefront experiencing these challenges in the United States, is essential.

The potential significance of this research is discussed in the final chapter; however, the researcher was optimistic that the results of this work would offer theoretical and practical value to academia, those who design legislation and policy, and all stakeholders involved in the advanced aviation industry. The three themes' theoretical significance lay in the emergence, providing a highly contextual understanding of UAM stakeholders' perceptions as a meaningful foundation for building and developing high-fidelity variables for further study. Additionally, using the premise of success from previous research exploring human perspectives, the findings contribute to the literature on human factors in aviation systems and fill a crucial gap. The results will benefit the industry by highlighting misalignment in safety assumptions and assisting in building safety and risk management frameworks. Finally, this chapter concluded with a discussion of the delimitations and limitations pointing to the potential and subsequent control for researcher bias, assumptions of participant honesty, ethical treatment, and earnest efforts of volunteer subject matter experts for their assistance in the refinement and validity of the instrument.

Definitions of Terms

Air Traffic Management	(ATM) The dynamic, integrated management of air traffic and airspace, including air traffic services, airspace management, and air traffic flow management, safely, economically, and efficiently through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions. (FAA, 2020b; International Civil Aviation Organization [ICAO] Doc 4444 PANS-ATM).
Air Navigation Service Providers	(ANSP) Provide information for strategic ATC separation services for UAM operations (FAA, 2020b).
Community Business Rules	(CBR) Collaborative set of UAM operational business rules developed by the stakeholder community. Rules may be set by the UAM community to meet industry standards or FAA guidelines when specified. CBRs will require FAA approval (FAA, 2020b).

Conflict	A point in time in which the predicted separation of two or more aircraft is less than the defined separation minima (FAA, 2020b).
Constraint	An impact to the capacity of a resource. Constraints can be natural (e.g., weather), circumstantial (e.g., runway construction), or intentional (e.g., temporary flight restriction) (FAA, 2020b).
Cooperative Separation	Separation based on shared flight intent and data exchanges between operators, stakeholders, and service providers and is supported by the appropriate rules, regulations, and policies for the planned operations (FAA, 2020b).
Demand Capacity Balancing	(DCB) Flight intent adjustments during the planning phase to ensure that predicted demand does not exceed the capacity of a resource (e.g., UAM Corridor, aerodrome) (FAA, 2020b).
Human-on-the-Loop	(HOTL) Human supervisory control of the automation (systems) where the human actively monitors the systems and can take

	full control when required or desired (FAA, 2020b).
Human-over-the-Loop	(HOVTL) Human informed or engaged by the automation (system) to take actions. Human passively monitors the systems and is informed by automation if and what action is required. Human is engaged by the automation either for exceptions that are not reconcilable or as part of rule set escalation.
Human-within-the-Loop	(HWTL) Human is always in direct control of the automation (systems).
Master Research Log	(MRL) The collection of researcher and subject-matter expert generated data from the study. Includes reflective journal notes, memos, concept models, and researcher tools.
Operational Tempo	The density, frequency, and complexity of operations.
Providers of Services for UAM	(PSU) An entity that assists UAM operators with meeting UAM operational requirements to enable safe and efficient use of UAM corridors and aerodromes. This service provider shares operational data with stakeholders and confirms flight intent.

PSU Network	A collection of PSUs with access to each PSU's data for use and sharing with their subscribers (FAA, 2020b).
Strategic Deconfliction	Deconfliction of UAM Operational Intent via advanced planning and information exchange (FAA, 2020b).
Subject-Matter Expert	(SME) An individual who has qualifications and specific knowledge in UAM and vertiports.
Tactical Separation	UAM operator responsibility for tactical conflict and collision avoidance (FAA, 2020b).
UAM Aerodrome	A location from which UAM flights arrive and depart (FAA, 2020b).
UAM Aircraft	An aircraft that can execute UAM operations.
UAM Corridor	An airspace volume is defining a three-dimensional route segment with performance requirements to operate within or cross where tactical ATC separation services are not provided (FAA, 2020b).
UAM Operation	The transport of people or goods from one aerodrome to another using UAM corridors.
UAM Operational Intent	Operation specific information including, but not limited to, UAM operation identification,

	the intended UAM corridor(s), aerodromes, and key operational event times (e.g., departure, arrival) of the UAM operation.
UAM Operator	The person or entity responsible for the overall management of a UAM operation; represents the organization that is executing the operation (FAA, 2020b).
UAS Traffic Management	(UTM) The manner in which the FAA will support operations for UAS operating in low-altitude airspace (FAA, 2020b).
UTM Operator	Operators conducting low-altitude UAS operations utilizing UTM-specific services (FAA, 2020b).

List of Acronyms

AAM	Advanced Air Mobility
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
CBR	Community Business Rules
ConOps	Concept of Operations
DAA	Detect and Avoid
DCB	Demand Capacity Balancing
DEP	Distributed Electric Propulsion
eVTOL	Electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration
FAA ANG	FAA Organization – NextGen Program Office
HOTL	Human-on-the-Loop
HOVTL	Human-over-the-Loop
HWTL	Human-within-the-Loop
ICAO	International Civil Aviation Organization
LOA	Letter of Agreement
MRL	Master Research Log
NAS	National Airspace System
NASA	National Aeronautics and Space Administration

NOTAM	Notice to Air missions
PIC	Pilot in Command
PSU	Provider of Services for UAM
RID	Remote Identification (ID)
SAA	Special Activity Airspace
SDSP	Supplemental Data Service Provider
SME	Subject-Matter Expert
SWIM	System Wide Information Management
TFR	Temporary Flight Restriction
UAM	Urban Air Mobility
UAS	Uncrewed Aircraft System
USS	UAS Service Supplier
UTM	UAS Traffic Management
V2V	Vehicle-to-Vehicle
VTOL	Vertical Take-Off and Landing

Chapter II: Review of the Relevant Literature

This chapter presents and discusses the relevant literature relating to the emerging urban air mobility, sometimes referred to interchangeably (although they are technically not interchangeable), as the advanced air mobility industry, and identifies challenges and concerns relating to the operational safety of advanced aircraft operations at vertiports from the stakeholder perspective. Therefore, literature about safety and stakeholder concerns was sourced from scholarly studies, government publications, and industry-published literature. This chapter is presented in four main sections. First, the introduction provides a broad overview of Advanced Air Mobility (AAM) and Urban Air Mobility (UAM), what and how it has evolved, community and passenger perspectives, and the parts that make up the UAM ecosystem.

Section two discusses the concepts and terminology of *vertiplaces*, a broad term for categories of vertical takeoff and aircraft landing areas also referred to as *vertiports*. Section three discusses the identified current challenges to advanced aircraft integration into the airspace and society and presents the contemporary literature relating to the proposed safety criteria and safety challenges relating to operations around the vertiports, including aircraft and flight considerations, passengers, and cargo. This section presents the literature forming the conceptual framework for the study design participant selection, examines the UAM roadmaps and concepts of operation, and focuses on the five critical challenge pillars and 24 barriers to UAM implementation; seven of these are overlapping and interdependent (Ellis et al., 2021; NASEM, 2018, 2020; NASA, 2020a; NUAIR, 2020, 2021a, 2021b; Patterson, 2021; Price et al., 2020).

Section four addresses the gaps in the literature, focusing on identified stakeholders' perceptions of their existing challenges and themes related to advanced aircraft operations and UAM vertiport safety. Finally, this chapter concludes with a summary of the key findings in the literature pertaining to stakeholder experience and perceptions and themes that emerge as the focal point of this study.

Introduction to Advanced Air Mobility

History has shown that humans have conceptualized and realized powered flight as a solution to hostile, congested, challenging, or arduous journeys and missions; aircraft have evolved to meet these needs and, in some ways, reflect the evolutionary journey of humankind itself (Orlady & Orlady, 1999). The first steps toward realizing the concept of personal air transport began soon after the Wright Brother's first powered flight, inspiring inventors and enthusiasts to conceptualize the possibility of flying cars as early as the 1910s and through the 1950s (Cohen et al., 2021; Gyger & Valery, 2011). However, none of these concepts were safe enough or viable for mass production and consumer adoption (Cohen et al., 2021; Patterson et al., 2021). Helicopter services provided a more realistic vision of personal air mobility and gained popularity in the 1950s; however, only society's wealthy and elite could afford this service. In the mid-1950s, two aviation companies, New York Airways, and Pan American Airways, were the first to offer these personal air mobility services, taking off vertically and landing on the rooftops of Manhattan, quickly transporting passengers to LaGuardia airport (Cohen et al., 2021).

These helicopter services heralded a new era of on-demand and scheduled personal air mobility. However, using helicopters poses significant challenges, including high operating costs and high noise levels (Goyal et al., 2018; Patterson et al., 2021; Uber Elevate, 2016). Today, the same concept, now called UAM, evolved from helicopter vertical takeoff and landing capability (Cohen et al., 2021). The modern UAM concept promises on-demand, affordable personal air transport connecting the average citizen from their neighborhood or city rooftops directly to airports, hospitals, train stations, and even neighboring towns and communities (Patterson et al., 2021; Rajendran et al., 2021; Uber Elevate, 2016).

While traditional helicopters and heliport operations provide a logical starting point to develop and implement UAM operations, this emerging industry presents some significant challenges and safety considerations for aviation regulators, airspace designers, system engineers, and equipment manufacturers, as well as public acceptance (Fillipone & Barakos, 2021; NASEM, 2018). Advanced Vertical Take-Off and Landing (VTOL) aircraft are considerably different in performance and capability than helicopters (Filippone & Barakos, 2020; Patterson et al., 2018); in addition, these aircraft will be operating in lower airspace and within closer proximity to buildings and urban infrastructure (Kopardekar, 2014; Pongsakornsathien et al., 2020). A 2018 market study conducted by the Booz Allen Hamilton (BAH) firm on behalf of NASA found that the potential UAM market demand could be worth $500 billion USD (Goyal et al., 2018). This figure estimates a mature UAM ecosystem, representing 11 million daily trips, approximately 20% of all daily work trips in the United States (Goyal et al., 2018). A recent study from the Government Accountability Office (GAO) found that according to data collected from publicly disclosed global investment, over $7 billion USD has been allocated for Advanced Aviation since 2019 (U.S. Government Accountability Office, 2022).

Defining AAM and UAM

Urban Air Mobility (UAM) was the original terminology used to describe vertical lift transport within cities and communities; however, in 2018, NASEM published the *Advancing Aviation Mobility National Blueprint* (2020). Subsequently, on March 23, 2020, NASA announced they would use the term Advanced Air Mobility (AAM) to describe the broader advanced air aircraft and missions operating in the airspace (NASA, 2020b; Patterson et al., 2021). The Federal Aviation Administration (FAA) delineates UAM as a more specific sub-set of AAM, describing UAM as the local ecosystem that provides access to the airspace through infrastructure developments to support takeoff and landing places and community engagement (FAA, 2020a, 2020b; NASEM, 2020). However, the reader should note that both terms are often used interchangeably throughout the published literature. Using both terms interchangeably is viewed by NASA and the FAA as inappropriate, considering the concept of operations (Patterson et al., 2021). Additionally, there were no formal definitions of each term from ICAO; therefore, this study uses the FAA and NASA terminology where possible.

Justification for Urban Air Mobility. UAM offers solutions to significant emerging problems in modern society primarily related to the increasing population in high-density cities. For example, in the United States, population increases in New York, Los Angeles, and San Francisco resulted in heavy ground transport congestion and long commute times (Goyal et al., 2018; Rajendran & Zack, 2019; Rajendran et al., 2021). This transport congestion results in other cumulative problems, including (a) lower worker productivity (Uber Elevate, 2016), (b) higher commuter frustration, higher stress, and a reduction in quality of life (Hennesy et al., 2000), and (c) increased environmental pollution through greenhouse gas emissions (Moore & Goodrich, 2013). Studies indicate that one of the significant advantages of UAM is the potential to significantly reduce urban congestion and commuter travel times, transforming commutes that would have taken over an hour to just a few minutes (Goyal et al., 2018; Holden & Goel, 2016; Rajendran et al., 2021).

Further to these studies, it is estimated that the dramatic reduction in worker commute times also offers the potential for reduced urban pollution and, therefore, contributes to global climate change mitigation (Kohlman et al., 2019; Moore & Goodrich, 2013). However, some argue that electric transport modes will produce just as much pollution due to battery production and charging requirements (Filippo & Brarakos, 2021). UAM is described as a transformative and disruptive new transport system that will support a safer, more efficient movement of people and cargo in increasingly congested urban environments (NASEM, 2020; Moore & Goodrich, 2013; Rajendran et al., 2021).

The safety benefits of UAM are primarily discussed around new advanced aircraft technologies, including electric or hybrid electric motors referred to as Direct Electric Propulsion (DEP) systems (Moore & Goodrich, 2013; Uber Elevate, 2016). These systems claim to support higher reliability levels than conventional engines and propulsion systems in helicopters and general aviation aircraft; higher reliability corresponds to higher levels of operational safety (Holden & Goel, 2016; Moore & Goodrich, 2013; NASEM, 2020). Therefore, UAM aircraft offer the potential for higher levels of safety than traditional helicopters and general aviation fleets (Moore & Goodrich, 2013).

However, real scenario testing of most of these aircraft has not been conducted (Filippo & Barakos, 2021). Proposed higher levels of safety using DEP are being promoted as an essential feature of UAM (Uber Elevate, 2016). Demonstrable safety and passenger perception of safety will be a crucial driver for UAM adoption (European Aviation Safety Agency [EASA], 2021a; Goyal et al., 2018; NASEM, 2020).

Demonstrated safety was a key factor missing in the 1910s to 1950s when flying cars were proposed. The overall justification for UAM in the predominant literature is that it will be a more efficient, safer, and more sustainable form of transport from the climate perspective (Kohlman et al., 2019; Moore & Goodrich, 2013; Patterson et al., 2021). UAM will also significantly reduce commute times for workers, lowering stress and increasing productivity and quality of life (Goyal et al., 2018; Hennessy et al., 2000; Rajendran et al., 2021). However, there are substantial gaps in the literature relating to potential challenges and risks around electric aircraft, aircraft components, total flight performance, and safety criteria (Filippo & Barakos, 2021.)

UAM Community Perspective

Community stakeholders are groups involved in and impacted by UAM operations; community stakeholders are represented by local, state, and tribal governments (NASA, 2021c; NUAIR, 2021). These stakeholders also may include educational institutions, hospitals, places of worship, and the residents in their jurisdictions. Positive perceptions and acceptance of UAM are critical components and challenges for successful implementation (Cohen et al., 2021; NASA, 2019; NASEM, 2020). However, studies have shown that while people are generally optimistic about the benefits of UAM, they are also concerned about safety, risk, noise, security, and privacy (Cohen et al., 2021; EASA, 2021a; Goyal et al., 2018; Patterson et al., 2021). Many of these concerns are yet to be fully understood and, in some cases, represent latent factors and hazards waiting to be discovered (Filippo & Barakos, 2021). Studies have investigated the central issue of trust in UAM as a service (Chancey, 2020; Chancey & Politowicz, 2020; Ragbir et al., 2018; Rice et al., 2014; Rice et al., 2019; Winter et al., 2015). However, there remain significant gaps in the literature relating to community stakeholder perceptions and acceptance of vertiplace size, access, location, parking, noise abatement procedures, regulations, and zoning (Filippo & Barakos, 2021; NUAIR, 2021). Additionally, local state and tribal governments' perceptions of the regulatory challenges of these issues have not been studied.

UAM Passenger Experience

For UAM to be sustainable, there must be a high passenger demand and passenger throughput (NUAIR, 2021; Rajendran & Zack, 2019; Rajendran et al., 2021) and, therefore, passengers must have a willingness to fly in them (Ragbir et al., 2021; Rice et al., 2015; Rice et al., 2020; Winter et al., 2020). Industry and government publications state that the vision for UAM is to support safe, efficient, and accessible [affordable] mass transit for everyone in the community, not just the wealthy and elite (FAA, 2020b; Patterson et al., 2021). This vision of UAM will incorporate passenger-friendly bookings with their portable electronic devices connecting them to other modes of transport, such as train stations, airports, and rooftop car parks and buildings (Goyal et al., 2018; Holden & Goel, 2016).

The first UAM service will likely be slightly higher in cost than a ground rideshare vehicle but significantly less than a helicopter or luxury limousine. UAM prices are estimated to be $6.25 per passenger mile, compared to $9.00 for a five-seat helicopter and a regular ground taxi at almost $3.00 per passenger mile (Goyal et al., 2018). The passenger ride-sharing model has gained success from the ground ride-sharing company Uber ® and is currently the proposed model for UAM (Holden & Goel, 2016; Goyal et al., 2018; NASEM, 2020; Rajendran et al., 2021). With many commuters in large cities experiencing commute times of 90 minutes or longer, UAM will provide a significant advantage (Ancliff et al., 2016).

Despite these advantages, passengers' major concerns include safety and quality of ride, vibration, noise, vehicle motion (pitch angles and roll rates), and ergonomic factors such as familiarity with cabin accommodations, including handholds, door handles, and seat adjustments (Edwards, 2019). However, due to the lack of UAM real experience or simulation capability (Edwards, 2019; Filippo & Barakos, 2021), there is a considerable gap in the literature for stakeholders to fully understand factors that will influence the passenger experience, especially when arriving and departing vertiports.

The UAM Ecosystem

Low Altitude UAM Airspace. In a market study conducted by Booz Allen Hamilton, a fully integrated UAM transport system plans to support millions of flights per day, representing 20% of all work trips (Goyal et al., 2018). These flights will transport people and cargo between rooftops, the tops of car parks, shopping centers, community centers, airports, and other locations (Ancliff et al., 2016; Goyal et al., 2018; Rajendran et al., 2021). This urban air traffic operates below 500 feet above the ground, closer to buildings, people, small uncrewed aircraft systems (UAS, sometimes called *drones*), and potential obstacles (Clothier et al., 2015b; Kopardekar, 2014).

With the rapid increase in drone use and the emerging UAM industry, NASA first proposed low-altitude traffic management in 2015 at the UAS Traffic Management Convention (Kopardekar, 2015; Syd Ali, 2019). Subsequent studies have investigated the integration of drones and UAM from various perspectives, including risk and safety (Belcastro et al., 2017; Clothier et al., 2015a; Clothier et al., 2015b; Lamb et al., 2020;

Myers & Truong, 2020). For the safe management of this urban airspace, the issue of traffic segregation and collision avoidance has been a critical consideration (Pérez-Castán et al., 2020; Pongsakornsathien et al., 2020; Ramasamy et al., 2018). To safely coordinate the proposed volume and diversity of this low-altitude traffic, urban air traffic management will be heavily reliant on advanced, automated, and integrated technologies on both the aircraft and at the control centers (Kopardekar, 2015; Pongsakornsathien et al., 2020; Syd Ali, 2019).

Current State of The National Airspace in The United States. The first formal steps to manage the airspace began at an international civil aviation convention in Chicago in 1944 (ICAO, 1944). However, a fatal mid-air collision over the Grand Canyon in 1956 prioritized the development of systematic Air Traffic Management (ATM) and shaped the system in use today (Kopardekar, 2014). According to the FAA, the United States operates 29.4 million square miles of airspace, the largest in the world. It supported 10.9 million jobs, accounted for over 5% of gross domestic product, moved nearly a billion passengers per year, and approximately 50,000 flights (FAA, 2020c). In addition, Congress has continued to pass key enabling legislative acts to keep pace with advancing aviation technologies. Examples include the National Technology Transfer and Advancement Act of 1995, which supports industry technical standards to achieve policy objectives (Dalamagkidis et al., 2008), the Vision 100, Century Aviation Reauthorization Act of 2003, and the FAA Reauthorization Acts of 2012 and 2018 (FAA, 2020c).

This modernization of the national airspace, called *NextGen*, currently accommodates uncrewed and autonomous systems for low-altitude operations, traditional airline and commercial operations, high-altitude autonomous aircraft for surveillance and communication, and commercial space flight operations (FAA, 2020c). The FAA has six classes of airspace, following International Civil Aviation Organization (ICAO) airspace classifications; the details of each are outlined in Figure 1.

Figure 1

Federal Aviation Administration Designated Classes of Airspace

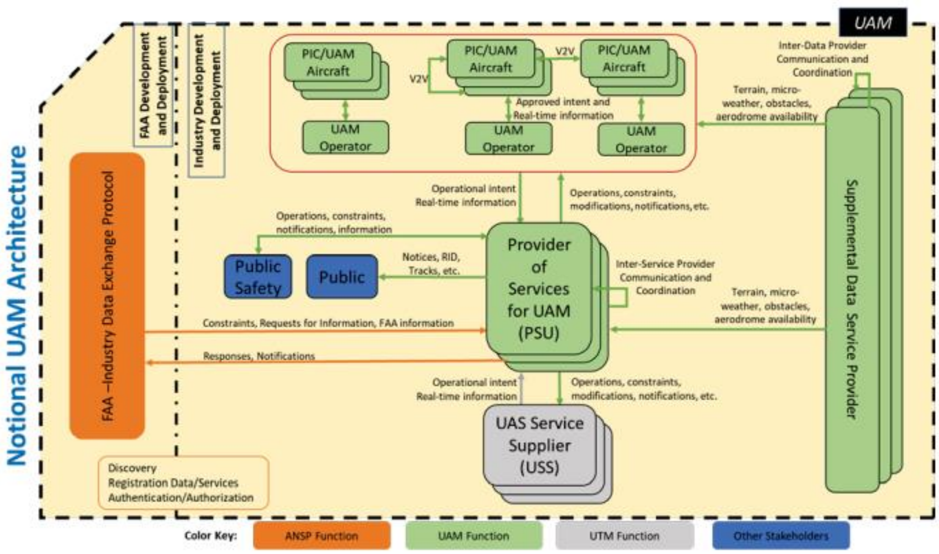
Airspace Class	Description
A	Class A encompasses the en route, high-altitude environment used by aircraft to transit from one area of the country to another. All aircraft in Class A must operate under IFR. Class A airspace exists within the United States from 18,000 feet MSL to and including 60,000 feet MSL.
B	All aircraft, both IFR and VFR, in Class B airspace are subject to positive control from ATC. Class B airspace exists at 29 high-density airports in the United States as a means of managing air traffic activity around the airport. It is designed to regulate the flow of air traffic above, around, and below the arrival and departure routes used by air carrier aircraft at major airports. Class B airspace generally includes all airspace from an airport's established elevation up to 12,000 feet MSL, and, at varying altitudes, out to a distance of about 30 nautical miles from the center of the airport. Aircraft operating in Class B airspace must have specific radio and navigation equipment, including an altitude encoding transponder, and must obtain ATC clearance.
C	Class C airspace is defined around airports with airport traffic control towers and radar approach control. It normally has two concentric circular areas with a diameter of 10 and 20 nautical miles. Variations in the shape are often made to accommodate other airports or terrain. The top of Class C airspace is normally set at 4,000 feet AGL. The FAA had established Class C airspace at 120 airports around the country. Aircraft operating in Class C airspace must have specific radio and navigation equipment, including an altitude encoding transponder, and must obtain ATC clearance. VFR aircraft are only separated from IFR aircraft in Class C airspace (i.e., ATC does not separate VFR aircraft from other VFR aircraft, as this is the respective pilot's responsibility).
D	Class D airspace is under the jurisdiction of a local Air Traffic Control Tower (ATCT). The purpose of an ATCT is to sequence arriving and departing aircraft and direct aircraft on the ground; the purpose of Class D airspace is to provide airspace within which the ATCT can manage aircraft in and around the immediate vicinity of an airport. Aircraft operating within this area are required to maintain radio communication with the ATCT. No separation services are provided to VFR aircraft. The configuration of each Class D airspace area is unique. Class D airspace is normally a circular area with a radius of five miles around the primary airport. This controlled airspace extends upward from the surface to about 2,500 feet AGL. When instrument approaches are used at an airport, the airspace is normally designed to encompass these procedures.
E	Class E airspace is a general category of controlled that is intended to provide air traffic service and adequate separation for IFR aircraft from other aircraft. Although Class E is controlled airspace, VFR aircraft are not required to maintain contact with ATC, but are only permitted to operate in VMC. In the eastern United States, Class E airspace generally exists from 700/1200 feet AGL to the bottom of Class A airspace at 18,000 feet MSL. It generally fills in the gaps between Class B, C, and D airspace at altitudes below 18,000 feet MSL. Federal Airways, including Victor Airways, below 18,000 feet MSL are classified as Class E airspace.
F	Not Applicable within United States
G	Airspace not designated as Class A, B, C, D, or E is considered uncontrolled, Class G, airspace. ATC does not have the authority or responsibility to manage of air traffic within this airspace. In the Eastern U.S., Class G airspace lies between the surface and 700/1200 feet AGL.

Note. From "Pilots Handbook of Aeronautical Knowledge," by the Federal Aviation Administration, 2016, U.S. Department of Transportation. In the public domain.

UTM Architecture. The FAA describes UTM services as a community-based traffic management system below 400 feet (above ground level) and includes a network of industry UAS service suppliers (USSs) (for drones) and a Provider of Services for UAM (PSUs) for advanced air mobility (FAA, 2020b, 2020c). The concept was developed in partnership with NASA and primarily provides for de-confliction and management of air traffic by layers of cooperative data exchange. The FAA retains oversight of UTM development through the UTM Pilot Program (UPP), which also serves as a testbed for integrating UAM operations. Figure 2 presents the NASA UTM architecture indicating the contextual flow of data sharing, including the USS and PSU roles and responsibilities.

Figure 2

Notional Urban Air Mobility Architecture



Note. From *NextGen Concept of Operations for Urban Air Mobility* (ConOps v 1.0) by the Federal Aviation Administration, 2020. In the public domain.

UAM Stakeholders in the UTM System. Some UTM stakeholders are pictured in the notional UAM architecture in Figure 2 and include a diverse range of organizations developing and testing aircraft, software, and navigation systems, all done with a high emphasis on collaboration through the NASA National Campaign (NASA, 2021b). For example, since the UAS Traffic Management Convention in 2015, hosted by NASA, industry stakeholders such as Google, Amazon, and Uber have worked with academia and the Federal Aviation Administration to test and develop the UTM framework (Syd Ali, 2019). In addition, the Uber ® partnership includes aircraft manufacturers such as Joby, Airbus, and ZeeAero (Ancliff et al., 2016; Rajendran et al., 2021; Uber Elevate, 2016). The massive collaborative effort also includes technical standards and certification bodies such as the American Society for Testing and Materials (ASTM), Society of Automotive Engineers (SAE), Radio Technical Commission for Aeronautics (RTCA), and the International Standards Organization (ISO) (Dalamagkidis et al., 2008; Goyal et al., 2018).

UTM Integration With UAM. The International Civil Aviation Organization ICAO is a specialized branch of the United Nations; its goal is to support harmonious, seamless, and safe aviation operations worldwide (ICAO, 1944). Although ICAO monitors the research and achievements on integrating UTM, it has yet to publish formal standards and recommended practices (SARPs), including definitions (ICAO, 2019). Therefore, the initial integration of UTM may differ between countries depending on their specific industry capability, including aircraft and environmental characteristics; for example, in China, the company EHang describes its vision of UTM through a centrally controlled, highly autonomous network (Xu, 2020). The European Union Aviation Safety Agency (EASA) adopted the first regulations on drone and UAM traffic rules on April 21, 2021, called U-Space/UTM, applicable in 2023 (EASA, 2021b; Pérez-Castán et al., 2020).

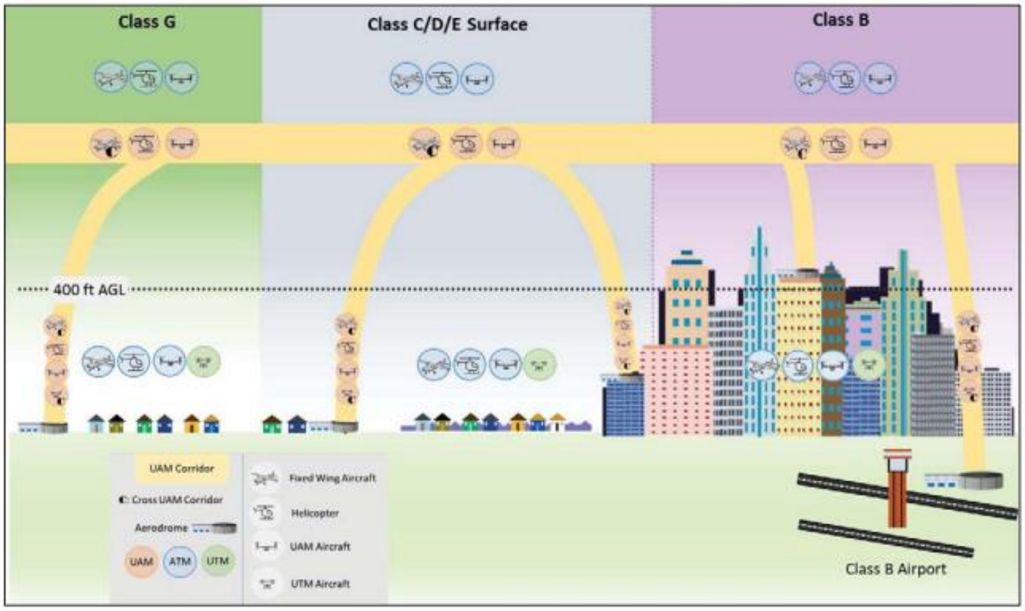
Similarly, the Australian Civil Aviation Safety Authority (CASA) described extending its regulatory framework within existing safety guidance from ICAO without explicitly detailing UAM/UTM integration details (Commonwealth of Australia, 2021). However, Australia is following the United States' model of industry-government collaboration; Embraer's UAM division Eve Air Mobility recently announced a partnership with Melbourne's local Victorian government and Airservices Australia for initial UAM services (Alcock, 2020). This Australian partnership outlined in Embraer's Urban Air Traffic Management ConOps (Airservices Australia & Embraer, 2020) is similar to the NASA UTM ConOps proposing a progressive timeline for implementation from simple, low-density, and piloted operations through to more complex, high-density, and automated and remotely piloted operations (Hill et al., 2020). UAM integration depends on the type of airspace and the capabilities, configuration, and performance type of advanced aircraft. Regulators in Australia, Europe, and the U.S. seem to agree that the progressive implementation of operations in UTM supports safety and risk mitigation (Clothier et al., 2015b; Hill et al., 2020; Pérez-Castán et al., 2020; Weibel & Hansman, 2004).

AAM Aircraft Types. It has been estimated that more than 100 advanced air mobility aircraft are in the prototype, development, or production phase globally (Filippone & Barakos, 2020; Sarsfield, 2019). Diverse in their design and performance, most rely on electrically driven propulsion and share vertical takeoff and landing capability, often collectively called eVTOL (electric, vertical takeoff, and landing) aircraft (Xu, 2020). These eVTOL aircraft have a passenger-carrying capacity of one person, for example, Germany's Volocopter, France's Airbus A3 Vahana, and the United States' Kitty Hawk Cora.

In addition, some have four to eight passenger capabilities, including Germany's Lilium Jet, Bell Helicopters Nexus, and Joby's S4 (Xu, 2020). eVTOL testing and pilot programs are in progress in various locations globally, some in conjunction with traditional aviation organizations such as Bell Helicopters, Airbus, and Embraer; other organizations are new entrants into the aviation industry, such as Joby. However, due to the diversity of eVTOL design, lack of performance standards, aircraft component certification, and regulations, significant gaps in the literature remain related to expected minimum safety performance parameters (Filippone & Barakos 2020).

Flight Corridors - UAM Streets in The Sky. Current studies indicate that dynamic modeling of UAM flights in a simulated UTM environment supports the calculation of collision risks, traffic sequencing, and UTM air route design (Pérez-Castán et al., 2020; Pongsakornsathien et al., 2020; Ramasamy et al., 2018). The FAA NextGen concept of UAM operations (version 1) outlines the use of UAM corridors connecting UAM aerodromes [vertiports] in the UTM class G, C/D/E, and B airspace, where both UAS and advanced aircraft will operate (FAA, 2020b). Flight in UAM corridors and within UTM airspace will follow some overarching principles, including UTM regulations and procedures that will integrate with the NAS. However, Stouffer et al. (2020) state that the challenges associated with remotely controlling aircraft via the frequency signals through air corridors within the dense urban core are not scalable within the projected NASA UTM maturity levels. The proposed UTM architecture will be scalable and safe, the FAA will retain regulatory and capacity balancing authority, and access must be equitable and flexible; PSUs, aircraft, and USS must share information and comply with the procedures (FAA, 2020b). The FAA illustration of the flight corridor example is presented in Figure 3.

Figure 3
UTM Corridors and NAS Operating Environments



Note. Flight corridors are presented in light orange, connecting the airspace types. From *NextGen Concept of Operations for Urban Air Mobility* (ConOps v 1.0) by the Federal Aviation Administration, 2020. In the public domain.

UTM Infrastructure. There are several components to the UTM infrastructure, including visible elements such as vertiports for aircraft arrival and departures, supporting infrastructures such as car parks and security points, the UTM control center(s), the communication and navigation towers, and satellites (NUAIR, 2020, 2021a; NUAIR, 2021b). In addition, the invisible component is the wireless radio spectrum, which supports many concurrent functions such as air traffic communication, navigation, and surveillance (FAA, 2020b; NASA, 2019; Stouffer et al., 2020; Stouffer et al., 2021).

NASA CONOPS. NASA's UAM vision statement is to "Revolutionize mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo" (NASA, 2020a; Patterson et al., 2021, p. 2). This vision will be achieved by a methodical, phased approach, starting slowly and then increasing to more complex operations, described as the *crawl, walk, run* approach (FAA, 2020b). Simulations and controlled scenarios support this approach, facilitating the discovery of potential hazards and helping to mitigate risks (Clothier et al., 2015b; FAA, 2020b; Hill et al., 2020; Pérez-Castán et al., 2020; Weibel & Hansman, 2004). Currently, NASA is working at the UAM Level of Maturity Four (ULM) Four (NASA, 2020a). UAM Maturity Levels One and Two involved initial testing through the various UAM Pilot Programs (UPPs). Subsequently, ULM Four involves starting isolated intermediate low-density low-tempo operations with the pilot onboard the aircraft (FAA, 2020b; Hill et al., 2020). Finally, the mature UML states Five and Six will apply progressively higher automated processes, some with pilot control remotely from a ground station, projected later in the 2020s into the 2030s (Hill et al., 2020).

The UAM Aerodrome: Vertiplaces

Evolution of the UAM Aerodrome

Within the *NextGen Concept of Operations for Urban Air Mobility* (FAA, 2020b), a UAM aerodrome is defined as "a location from which UAM flight operations depart or arrive…UAM aerodrome is used explicitly when the context indicates functionality to support UAM operations that are not present in current NAS operations" (p. 11). This terminology is consistent with FAA NextGen UAM operations documentation (Patterson et al., 2021). However, stakeholders in published industry studies and working groups use the terms vertiports, vertihubs, and vertistops, collectively referred to as vertiplaces, rather than UAM aerodromes (Cohen et al., 2021; National Air Transport Association [NATA], 2019; NUAIR, 2020a, 2021; Sarsfield, 2019). Considering this literature, the term UAM aerodrome may emerge as the primary regulatory term encompassing the sub-categories of vertiplaces. This study will use the sub-category terms to align with the language used by the stakeholder working groups (NUAIR, 2020a, 2020b).

Traditional Heliport Design. Most civilian helicopters carry fewer than nine passengers and mainly operate *on-demand services* (ODS). These ODS flights fall under the general and private operations category rather than scheduled aviation operations (FAA, 2021a). As a result, certification to the FAA heliport design standards is considered a low priority and not of public interest; therefore, certification is voluntary unless in conjunction with federally funded airport improvement programs or revenue from passenger facility charges (FAA, 2021a). Thus, voluntary certification provides no legal authority for the FAA to enforce standards or provide oversight (NUAIR, 2021). As a result, only one heliport out of 5,918 in the United States has been certified to the FAA design standards.

Heliport design standards were charted in FAA Advisory Circular (AC) 150/5390; shortly after, vertiport standards were outlined in AC 150/5390-3. The vertiport design AC was subsequently canceled on July 28, 2010, due to the incompatibility with most vertical takeoff and landing aircraft use. However, the term vertiport remains in 14 CFR§157.2 (NUAIR, 2021b). The current version for heliport standards is AC 150/5390D, published in 2023, which provides criteria including dimensions of touchdown and lift-off areas (TLOF), final approach and takeoff areas (FATO), consideration for turbulence effects, dimensions for parking, and taxi routes, airspace approach and departure routes, lighting, ground markings, signage, protected areas, fire protection, emergency use, and other elements and components.

Evolution of Vertiport Guidance. It is reasonable to believe that traditional helicopter standards and guidance material for heliports are logical for developing vertiport design standards. However, these existing standards are not appropriate for the emerging advanced eVTOL aircraft for UAM and may subsequently stifle future operational progress (FAA, 2021b; Stouffer, 2020). Therefore, in 2019 and again in 2021, the FAA reached out to industry stakeholders with a request for information (RFI) regarding (a) AAM aircraft designs and performance capabilities and (b) a proposed concept of operations as a starting point for vertiport design standards for UAM operations (FAA, 2021b). Subsequently, the FAA research heliport at the FAA William J. Hughes Technical Center serves as a vertiport testbed while ongoing studies investigate related challenges such as vertiport charging needs, cyber security concerns, hazard evaluations, automation levels, and gap analysis. The FAA plans to publish the new vertiport interim guidance by June 2022, with the final vertiport AC by September 2024 (FAA, 2021b). However, without explicit definitions and understandings of the operational environment, legacy AAM designs and performance may outpace initial vertiport concepts, restricting the scalability of operations (Stouffer et al., 2020; Stouffer et al., 2021).

The Vertiplace Concept

A recent industry trade study led by NASA produced a description of vertiplaces for AAM. This trade study proposed three main categories of UAM takeoff and landing areas collectively called *vertiplaces* (NUAIR, 2020). The umbrella term vertiplaces collectively align with the FAA's regulations relating to conventional aircraft takeoff or landing areas defined in 14 CFR §157.2 and ICAO’s definition of an aerodrome as a defined area on land or water (including any buildings, installations, and equipment) intended to be used either wholly or in part for the arrival, departure, and surface movement of aircraft (ICAO Annex 14, Manual of Standards, 1999). However, the study also proposed the term *vertilates* to convey additional and diverse ranges of services and autonomy levels of operations in vertiplaces (NUAIR, 2020, p 2.), the term was only mentioned once in the study, and no examples were provided. Still, this term does not appear in subsequent or older supporting literature. The lack of unified terminology and definitions relating to AAM and UAM compounds challenges building a regulatory framework.

Vertiplace characteristics and categories will differ in operational tempo (frequency of takeoff and landings) and density (number and type of aircraft traffic). For example, a *vertihub* is the most complex category of vertiplace, servicing a high tempo density of operations. At the same time, a verti*port* will operate a moderate tempo and be limited to certain types of aircraft, and lastly, a verti*stop*, which is envisioned as the smallest of the vertiplace, will be primarily for passenger or cargo drop-off or pick-up (NUAIR, 2021a, 2021b). The vertiplace terminology is not explicitly mentioned in the NASA UAM vision of operations for UAM maturity Level Four or the FAA UAM concept of operations. In much of the other literature, this emergent concept is referred to as vertiports. Figure 4 presents the industry trade study proposal of the three sub-categories of the vertiplace concept.

Figure |4

Vertiplace Concept Sub-Categories: Vertihub, Vertiport, Vertistop

Note: From *National Aeronautics and Space Administration Advanced Air Mobility Vertiport Automation Trade Study*, by Northeast UAS Airspace Integration Research Alliance, 2020, NTRA NASA Technical Reports Server. In the public domain.

Vertihubs. According to NUAIR (2020), vertihubs are designed with high-density UAM traffic. It is envisioned that vertihubs will be a mass transit UAM center co-located with other public transport nodes, like airports, train stations, and bus terminals (NUAIR, 2021a; Xu, 2020). Vertihubs will likely have passenger lounge facilities and maybe a transfer hub connecting to other UAM or regional air mobility (RAM) services. Vertihubs may have the capacity to park and store aircraft and have Maintenance Repair and Overhaul (MRO) facilities attached to them (NUAIR, 2021a, 2021b). Very few publications explicitly use the term vertihub and instead use vertiport or high-density vertiport (Pongsakornsathien et al., 2020; Sarfsfield, 2019; Stouffer et al., 2021).

Vertiports. Vertiports are described as likely smaller in size, complexity, and operating tempo (NUAIR, 2020). They are likely located in urban core environments close to or co-located with other transport nodes or community centers such as shopping malls or hospitals (NUAIR, 2020). Volocopter, a German AAM company, is developing a prototype of vertiports and using the terms *voloports* and *skyports*; these are being built in Germany, Singapore, and Australia and are planned for full operation by early 2023 (Alcock, 2020; NUAIR, 2021b; Sarsfield, 2019). Similar to heliports, vertiports may have several takeoffs and landing *pads* to accommodate simultaneous arrivals and departures.

Vertistops. Vertistops are described as the smallest element of the vertiplace categories. Vertistops will likely serve as a passenger connection point and likely have no maintenance staff, even if it is used as a charging station (NUAIR, 2020). These vertistops will probably only have a single takeoff and landing pad for quick passenger or package transfer, which is described as a characteristic of the *last mile* component of a journey (NAIR, 2020).

UAM Vertiplace Stakeholders

The UAM vertiplace stakeholders are the central focus of this proposed research; the literature in this section is the foundational literature for the conceptual framework. The initial investment in vertihub and high-density vertiport infrastructure is estimated to be approximately $35 to $45 million dollars, with annual operating costs between $110 million to $130 million per year (Johnston et al., 2020). The primary stakeholders directly involved in the operation of an advanced aircraft landing and taking off from a vertiport in a normal scenario include the flight crew and aircraft crew, AAM fleet operator, vertiport manager, providers of services for UAM, the FAA, and local and state governments. Each stakeholder is either directly or indirectly responsible, accountable, consulted, and informed (RACI) about operational status and any deviation from normal operations that may trigger a safety issue (NUAIR, 2021a). Figure 5 presents an overview of the stakeholders and their responsibility for typical flight phases at a vertiport. The figure is called the RACI Matrix, and it provides a high-level perspective of stakeholders' allocated roles and responsibilities.

Figure 5

The RACI Matrix of Stakeholder Roles and Responsibilities

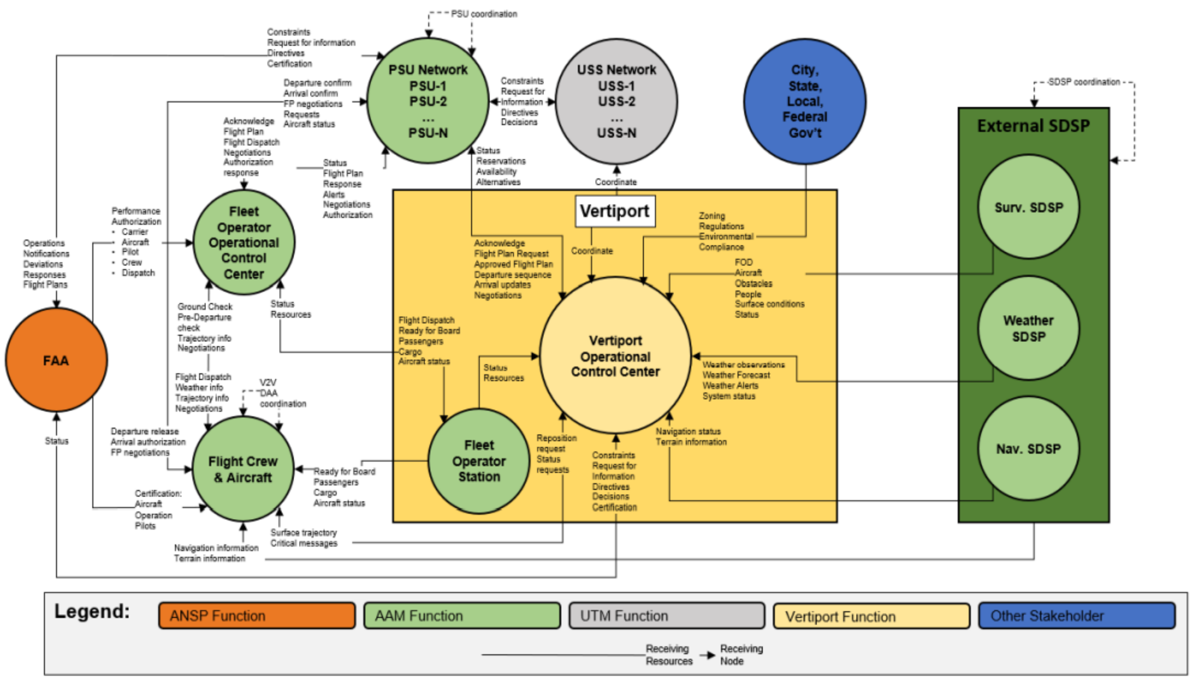
Phase of Flight	Flight Crew and Aircraft	Fleet Operator	Vertiport Manager	Monitoring PSU	FAA, State and Local Government
Pre-Flight	R	A	I	C	I
Emplane	R	A	C	I	I
Taxi	R	A	C	I	I
Takeoff	R	A	C	C	I
Climb	R	A	I	C	I
Cruise	R	A	I	C	I
Approach	R	A	C	C	I
Land	R	A	C	C	I
Taxi	R	A	C	I	I
Deplane	R	A	I	I	I
Post-flight	R	A	I	C	I

Note. The figure shows whether the stakeholder is Responsible, Accountable, Consulted, or Informed on each phase of the flight. From *High-density automated vertiport concept of operations* by Northeast UAS Airspace Integration Research Alliance, 2021, NASA Technical Reports Server. In the public domain.

High-density vertiports will support dynamic and complex UAM operations. It will depend on various levels of automation, human oversight, control, or how involved the human is with the information *loop* of automated functions (NASA, 2020a; Patterson et al., 2021). Thus, other stakeholders will be indirectly connected and impact vertiport operations within the automated system architecture. These stakeholders may include essential or ancillary services providers such as supplementary data and software, technical components, charging components, and human assets (Ellis et al., 2021; NUAIR, 2021a, 2021b). In addition, indirect stakeholders must be activated in an off-nominal or emergency scenario, such as emergency services, cyber security services, and law enforcement. Figure 6 presents an overview of the vertiport concept of operations and automated system, which provides an overview of the roles and responsibilities of some of the stakeholders in a normal scenario, including the FAA, ANSP, AAM, UTM, Vertiport Function, external Supplemental Data Service Provider (SDPS), Provider of Services for UAM (PSUs), and city, state, local, and federal government.

Figure 6

Vertiport Automation System: Direct and Indirect Stakeholders



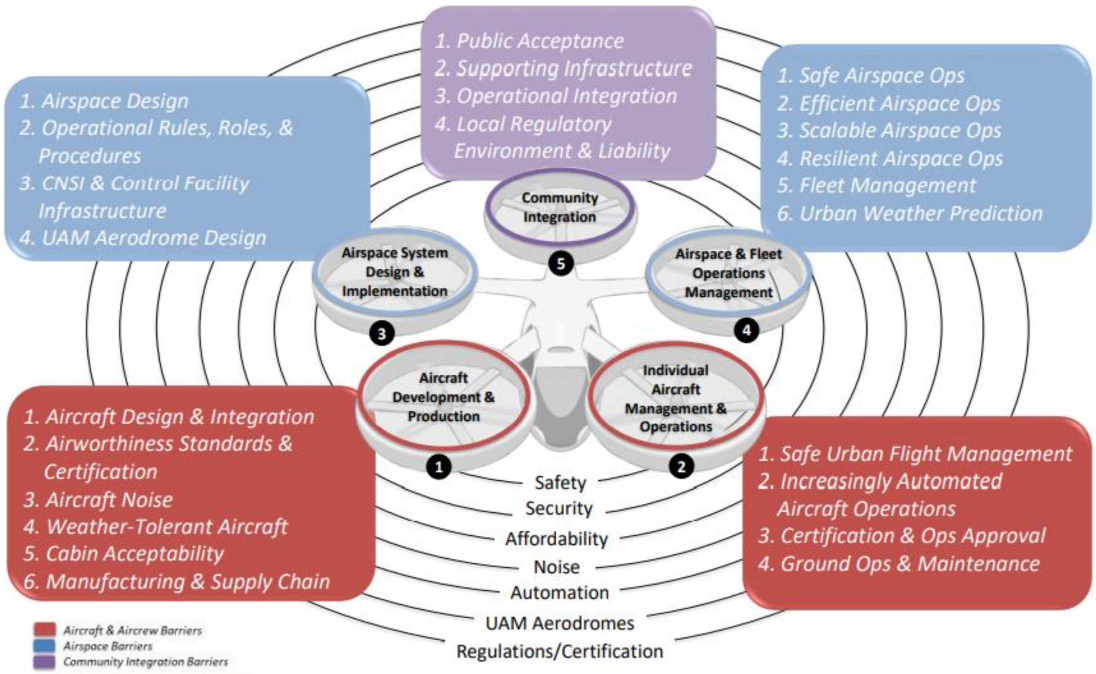
Note: From *High-density automated vertiport concept of operations*, by Northeast UAS Airspace Integration Research Alliance, 2021, NASA Technical Reports Server. In the public domain.

Significant Challenges to UAM Integration

One of the most notable collaborative efforts to identify and discuss UAM challenges to integration is detailed in the NASA Vision for ULM Level Four concept of operations (NASA, 2020a). Producing the ConOps involved consulting with over 100 industry stakeholders, conducting more than two dozen interviews with subject matter experts, and considering more than 160 sources of literature from scholarly, regulatory, and industry sources (NASA, 2020a; Patterson et al., 2021; Price et al., 2020). The final results produced a high-level UAM framework dividing integration challenges into five critical challenge pillars. In addition to the five challenge pillars, 24 barriers to implementation were identified; seven of these barriers were common to each challenge pillar (Patterson et al., 2021). Furthermore, these seven common barriers that transcended the challenge pillars' boundaries are often highly interdependent; these were named *crosscutting barriers* (NASA, 2020a; Patterson et al., 2021; Price et al., 2020). The challenge pillars and barriers framework provided NASA with a methodology for organizing working groups (WGs) to investigate possible solutions. The four working groups include (a) *aircraft and aircrew* barriers, (b) *airspace* barriers, (c) *community integration* barriers, and finally, (d) the *crosscutting* working group (NARI, 2021). Figure 7 shows the NASA UAM framework, with the five challenge pillars and the seven crosscutting barriers (represented by the concentric black rings). The five challenge pillars are numbered; challenge pillars one and two are the shared focus of the aircraft and aircrew barriers WG. Challenge pillars three and four are the shared focus of the airspace barriers WG, while challenge pillar five has a dedicated WG called community integration barriers WG. The crosscutting WG is comprised of both members from the other WGs, and dedicated members.

Figure 7

NASA UAM Framework Barriers, UAM ConOps UML Four



Note. From *NASA Advanced Air Mobility Ecosystem Working Groups Portal*, by (NASA Aeronautics Research Institute, [NARI], 2021). In the public domain.

The Five NASA Pillars

Challenge Pillar One: Aircraft Development and Production. This pillar addresses seven challenges, including (a) aircraft design and integration, (b) airworthiness standards and certification, (c) aircraft noise, (d) weather tolerance, (e) cabin acceptability, and (f) manufacturing and supply chain challenges (NARI, 2021; NASA, 2020a; Patterson et al., 2021). These challenges are interdependent; for example, aircraft designs and manufacturing processes will directly impact airworthiness certification and operational approvals. Additionally, these aircraft designs must be scalable, demonstrate reliability and tolerance to weather and other environmental impacts, and demonstrate performance capabilities that ensure safe flight within the highly constricted urban ecosystem (NASA, 2020a; Patterson et al., 2018; Patterson et al., 2021; Stouffer et al., 2020; Stouffer et al., 2021).

Aircraft Design and Integration. Challenges to making AAM aircraft compatible with the UAM aerodromes require collaboration from relevant stakeholder groups; over 200 original equipment manufacturers (OEMs) are developing eVTOL aircraft and associated systems (Ferrell & Anderegg, 2020; Sarsfield, 2019). Therefore, the diversity of designs and equipment must have uniformity in their functional and safety performance to integrate with the UAM ecosystem (Ferrell & Anderegg, 2020; NASA, 2020a; NASEM, 2020; Stouffer et al., 2021). In addition, as UAM is still an emerging industry, many eVTOL designs are still in the test phase (Sarsfield, 2019). Therefore, these systems' safety performance and actual capabilities remain unknown (Fillipone & Barakos, 2021; McSwain et al., 2020).

Airworthiness Standards and Certification. There is an effort within the standards organizations such as RTCA, ASTM, and SAE to adapt existing standards and develop new standards for eVTOL aircraft and equipage, especially regarding safety-critical components (Ferrell & Anderegg, 2020; Goyal et al., 2018). However, there are significant gaps in the literature regarding how eVTOL aircraft will perform due to a lack of real-world tests and the cost of simulations (Filippone & Barakos, 2020; McSwain et al., 2020). These challenges also relate to the features within the passenger cabin to support passenger comfort, access, and functionality for both able and disabled passengers (FAA, 2021b; Kim et al., 2021).

Aircraft Noise. The challenges relating to aircraft noise are not unique to UAM operations. Case law involving aircraft noise and other complaints associated with airports dates back as early as the 1930s, setting the legal precedent that aircraft and airports have a place in the modern community (Wolf, 1948). In San Francisco, all helicopter operations are prohibited because of the low community acceptance of noise (Antcliff et al., 2016). Current studies indicate that aircraft noise is a significant concern for UAM integration, especially community acceptance (EASA, 2021a; FAA, 2020b; Yedavalli & Mooberry, 2019). These noise concerns are different for various stages of flight, such as en route, takeoff, and landing (EASA, 2021a; NASEM, 2020), time of day, and traffic volume (Yedavalli & Mooberry, 2019). Because most eVTOL aircraft will have direct electric propulsion or hybrid powertrains, they will be less noisy than regular helicopters; however, eVTOL propellers will generate noise scalable to their size (Antcliff et al., 2016). One of the most significant gaps within the literature concerns regulations and standards relating to UAM, including acceptable noise thresholds for vertiports and UAM flight routes.

Weather Tolerant Aircraft. Designing eVTOL to be resilient in weather and environmental conditions provides significant challenges to eVTOL aircraft; in addition, these designs must be certified as safe by regulatory agencies. Furthermore, some environmental conditions are unique to the UAM ecosystem and not detected by traditional aviation forecast methods, for example, local urban icing conditions, turbulence created by urban canyons or building structures, higher winds above-ground levels, and pockets of low visibility (Adkins et al., 2020; Goyal et al., 2018; NASA, 2020a; Reiche et al., 2019). UAM airdromes may have to stipulate specific aircraft performance criteria or design functions to mitigate hazards associated with local weather phenomena. This issue represents a gap within the literature, which is identified but not examined.

Cabin Acceptability. Passenger comfort and the quality of the ride are important and complex factors to understand and design for the eVTOL aircraft. Factors such as vibration, noise levels, interior climate control, and lighting contribute to the passenger experience (Edwards, 2019; NASA, 2020a). In addition, other features, such as ease of access, such as handles, ergonomic features, tray tables, and cup holders, help make the vehicle feel familiar and the passengers feel comfortable (Edwards, 2019; NATA, 2019). However, few studies examine passenger reactions and comfort levels in eVTOL aircraft due to the availability of costs associated with eVTOL simulators and a lack of real-world testing (Edwards 2019 Filippone & Barakos, 2021).

Manufacturing and Supply Chain. A significant challenge facing UAM implementation is the requirement for rapid production, high volume of eVTOL aircraft, and associated components. Additionally, aircraft and components must be certified as safe and compliant, equivalent to aviation standards (McSwain et al., 2020; NASA, 2020a; Patterson et al., 2021). Further, the supply chains must meet the requirements for maintenance, repair, and overhaul (MRO) of eVTOL aircraft operations (Beilharz, 2021; McSwain et al., 2020). There is a shared view by OEM stakeholders and experts that if these challenges are to be solved, UAM production must replicate the manufacturing and supply chain characteristics of the automotive industry (Beilharz, 2021; Grealou, 2015; McSwain et al., 2020).

Challenge Pillar Two: Individual Vehicle Management. Pillar two challenges represent four main areas: (a) safe urban flight management, (b) increasingly automated aircraft operations, (c) certification and operation approval, and (d) ground operations and maintenance. Many of the challenges mentioned above regarding certification and maintenance overlap between pillars and are assigned to one working group, Aircraft and Aircrew (NASA, 2020b). However, this challenging area brings into focus some of the human factors at the various levels of managing the automation in controlling the vehicle *over-the-loop monitoring* (Clare et al., 2015; Cummings et al., 2014; Patterson et al., 2021).

Safe Urban Flight Management. Although the challenges associated with UAM urban flight planning, including the critical functions of communication, navigation, and surveillance (CNS), have been identified in the literature (Pérez-Castán et al., 2020; Pongsakornsathien et al., 2020), there are significant challenges in making these capabilities a practical reality (Stouffer et al., 2020; Stouffer et al., 2021). In addition, other challenges, including emergency and contingency scenarios, are yet to be fully understood; for example, a pilot on board becoming incapacitated or a fire or failure of the battery/propulsion system, CNS, or cyber-attack (NASA, 2020a; Patterson et al., 2021).

Increasingly Automated Aircraft Operations. ULM-4 UAM aircraft are not likely to be fully automated; however, increasingly automated aircraft will change the traditional roles and responsibilities involved in how aircraft are managed (Patterson et al., 2020). AAM, UAM, and UAS operations will likely rely on various levels of autonomy, and a human actor will monitor critical safety functions over the loop of one or multiple aircraft (Clare et al., 2015; Cummings et al., 2010; Cummings et al., 2014; Patterson et al., 2021). These operations involving various levels of human-automation collaboration present significant challenges, including trust and bias in automation (Clare et al., 2015), operator performance and workload (Cummings et al., 2010), roles and responsibilities (Patterson et al., 2021), and standards for controls and displays (Vu et al., 2020).

Certification and Operations Approval. Certification and operations approvals are significant barriers to UAM and UTM integration (Kopardekar, 2014; NASA, 2020a; NUAIR, 2020; Stouffer et al., 2021), especially regarding operations of vertiports (NUAIR, 2021a, 2121b). Additionally, through this lens of safety and compliance, the highly automated UAM ecosystem represents a significant paradigm shift from the deterministic systems in traditional aviation (Ferrell & Anderegg, 2020). Vu et al. (2020) discuss the challenges of developing UAS detection and avoidance standards and displays, which would be critical in how the human actors would monitor and understand the separation of UTM air traffic. Standards bodies such as the American National Standards Institute (ANSI), the International Standards Organization (ISO), RTCA, and ASTM continue to work with the industry to work toward standards that support certification for UAM and UAS operators (Ferrell & Anderegg, 2020; McSwain et al., 2020).

Ground Operations and Maintenance. Some vertiports within the UAM ecosystem will have varying passenger services and facilities, especially those described as sky ports (Sarsfield, 2019), high-density vertiports, and vertihubs (NASA, 2020a; NATA, 2019; NUAIR, 2020). The challenges that stakeholders have identified to date are associated with the design to facilitate aircraft movement and parking, human resources, training, roles, and responsibility considerations. These challenges are identified and discussed as they relate to the role of the UAM airport operator (Patterson et al., 2021). However, there are significant gaps within industry and scholarly literature addressing these challenges and exploring unknown challenges that will likely emerge in real-world scenarios.

Challenge Pillar Three: Airspace System Design and Implementation. Pillar three challenges include (a) airspace design, (b) operational rules, roles, and procedures, (c) Communication Navigation Surveillance Information (CNSI), and (d) UAM aerodrome design. The NASA working group for this pillar is the Airspace Barriers group (NASA, 2020a).

Airspace Design. The UAM ecosystem will support a diverse range of advanced aircraft, including UAS and passenger-carrying eVTOL aircraft; all will have varying degrees of autonomy, performance, and capabilities (Kopardekar, 2014; Kopardekar et al., 2016). Therefore, the airspace design must be practical, feasible, scalable, equitable, and implementable (FAA, 2020a, 2020b; NASA, 2020b; Patterson et al., 2021). In addition, airspace design must consider noise, privacy, and traffic density and balance these with community and passenger concerns and needs (FAA, 2020b; EASA, 2021a; Goyal et al., 2018; Rajendran et al., 2021).

Operational Rules, Roles, and Procedures. The NASA UTM architecture presents the theoretical framework for how ground systems such as SDPs and SSPs will work together in the UAM ecosystem; the architecture is complex and includes human controllers, pilots, and dispatchers (Kopardekar et al., 2016). Therefore, guidance, rules, and procedures must be technology-agnostic and goal-based to support synergy and safety across the automated airspace system (Ferrell & Anderegg, 2020; Kopardekar, 2014, 2015; NASA, 2020a; Patterson et al., 2021).

Communication Navigation Surveillance Information. Challenges relating to CNSI range from placement and security of physical infrastructures, such as towers, ground and satellite relay mechanisms, and the frequency characteristics concerning quality, latency, resilience, resolution, and signal availability (NASA, 2020a; Patterson et al., 2021; Stouffer et al., 2020; Stouffer et al., 2021). There are challenges regarding the safety of the national airspace related to the 5 GHz spectrum security, allocation, and how it may interfere with traditional aircraft CNSI equipment (Niles, 2021; U.S. Department of Transportation, 2020).

Challenge Pillar Four: Air Traffic & Fleet Operation Management. The Airspace Barriers working group focuses on this pillar concurrently with pillar three (airspace design and implementation), as many of the challenges of both pillars are interdependent (NASA, 2020a). The fourth pillar includes six distinct challenges: (a) safe, (b) efficient, (c) scalable, and (d) resilient airspace operations, (e) fleet management, and (f) urban weather prediction. As many of the challenges mentioned overlap within the literature presented thus far, this section will discuss safety and urban weather prediction.

Safe Airspace Operations. Safe UAM airspace operations will depend upon identifying and predicting risks to safety performance across the entire UAM ecosystem of systems (Ellis et al., 2021; Ferrell & Anderegg, 2020). UAM system-wide safety assurance will depend upon a thorough understanding of factors in normal, contingency, and emergency operations (FAA, 2020b, 2020c; NASA, 2020a). In addition, safe UAM operations will rely heavily on sensors to mitigate factors such as mid-air collision, safe separation, and scheduling (Pongsakornsathien et al., 2019; Ramasamy et al., 2018). Interpreting and reacting to these factors will require an understanding of human factors integration, such as multi-crew teaming, situational awareness, and non-technical skills (Endsley & Jones, 2011; Flin et al., 2008; Orlady & Orlady, 1999).

Therefore, safe airspace operations will require a fusion of innovative and automated systems with traditional aviation systems; as a result, the whole UAM ecosystem will need to be goal-based, auditable, and scalable and consider human safety culture (Ferrell & Anderegg, 2020). As a result, the NASA working groups have proposed the In-Time Aviation Safety Management System (IASMS) (Ellis et al., 2021); however, IASMS is in the early stages. In addition, there are significant gaps in the literature; a lack of studies explaining latent hazards that may emerge from the fusion of system boundaries and human safety culture within the UAM ecosystem means multiple safety issues remain largely unexplained.

Urban Weather Prediction. Weather phenomena such as strong wind gusts, turbulence, snow, ice, fog, and heavy rain can threaten the safe operations of all aircraft. Additionally, the urban environment makes a micro-weather phenomenon that can pose severe hazards and challenges to UAM operations; buildings, structures, and other locations can form urban canyons and create microclimates where hazardous conditions remain undetectable (Adkins, 2020; NASA, 2020a; Reiche et al., 2019). In addition, Ragbir et al. (2021) indicated that weather conditions have an impact on passengers' willingness to fly in AAM. The challenges for UAM stakeholders include determining weather policy and regulations, mechanisms for communication and sharing of UAM weather, roles and responsibilities, data collection and forecast modeling, cost structure for services, and legal obligations of the providers (NASA, 2020a). Despite the lack of studies relating to these challenges, some innovative solutions to weather data in UAM microclimates may include non-traditional sensors that use the Internet of Things (IoT), such as smartphones, social media, crowdsourcing, and personal weather stations

(Adkins, 2020). However, there remains a gap in the literature examining the suitability of these innovative solutions.

Challenge Pillar Five: Community Integration. The community integration pillar includes four primary areas, including (a) public acceptance, (b) supporting infrastructure, (c) operational integration, and (d) local regulatory, environmental, and liability issues (NARI, 2021). The NASA Community Integration Barriers working group focuses on this single pillar and collaborates with the Crosscutting working group. The community integration pillar represents arguably the most critical challenge to UAM integration, as it addresses public concerns about safety, security, affordability, privacy, noise, emissions, and liability of UAM in their communities (Cohen et al., 2021; NATA, 2019; Yedavalli & Mooberry, 2019).

***Public Acceptance*.** Public acceptance is critical to unlocking demand for UAM services (Anania et al., 2018; Goyal et al., 2018; Rice et al., 2019; Winter et al., 2014, 2020). Although these concerns manifest at the individual level, personal perceptions of safety, trust, and a willingness to fly in autonomous and advanced aircraft like those proposed for UAM will impact daily life and are critical considerations to community acceptance (Anania et al., 2018; Chancey & Politowicz, 2020; Ragbir et al., 2021; Rice et al., 2019; Winter et al., 2014, 2020). These community integration concerns appear to be shared worldwide, with studies indicating European, East Asian, and Asian Pacific communities prioritize safety concerns first and then, with various degrees of importance: noise, security, privacy, and accessibility (Alcock, 2020; EASA, 2021a; Commonwealth of Australia, 2021; Rice et al., 2014; Ward et al., 2021; Winter et al., 2020; Yedavalli & Mooberry, 2019). NASA believes that UAM safety, public confidence, and acceptance of UAM can be supported by holding public demonstrations of UAM aircraft tests and operations (NASA, 2020b). Public demonstrations of UAM safety will also help increase familiarity with these advanced aircraft and autonomous systems, a significant factor in the willingness to fly in autonomous commercial airplanes (Rice et al., 2019).

***UAM Supporting Infrastructure*.** Supporting infrastructure includes the physical enablers of the UAM ecosystem, including UAM aerodromes, the battery and energy requirements, and UAM test ranges (NASA, 2020a; Price et al., 2020). From a community integration perspective, the location and design of vertiports will require a significant amount of planning and consideration by all industry stakeholders (NATA, 2019; NUAIR, 2020). These considerations in the published literature indicate broad, high-level concepts in the early stages of discovery (NASA, 2021c; NATA, 2019; NUAIR, 2021a, 2021b), which is confirmed in supporting literature (Patterson et al., 2018; Patterson et al., 2021; Price et al., 2020). However, another significant gap in the current literature is studies examining supporting infrastructure impacts at the interactive and granular level, particularly as they relate to UAM aerodromes and the stakeholders who will be responsible for UAM operations.

***Operational Integration*.** Critical to UAM integration is understanding the operational challenges of passenger flow and connecting UAM passengers seamlessly and safely with other modes of transport to support a positive passenger experience (Yedavalli & Mooberry, 2019). For example, passengers may book a flight but have to connect from one vertiport to another and then into the regular airport passenger movement area at an airport (NASA, 2020a; Rajendran et al., 2021). For successful integration, UAM must be a harmonious part of a multimodal transport system that alleviates stress and frustration associated with long commutes (Goyal et al., 2018; Hennessy et al., 2000; Rajendran et al., 2021). Operational integration also implies that passengers and cargo will be screened and processed to mitigate security risks. Scheduling must be compatible with other modes of transport schedules and resilient to disruption of UAM services (NASA, 2019, 2020a; NUAIR, 2021a). Much of the published literature presents aspirational high-level concepts of UAM; however, few studies have examined the stakeholders' perceived challenges through the lens of operational integration in detail.

***Local Regulatory, Environmental, and Liability Issues*.** The courts have long recognized that the law trails behind technology and innovation, particularly transport innovations like UAM (Ravich & Carl, 2021). Stakeholders representing the community's interests have many challenges and controversies yet to be fully understood and solved, such as developing zoning, taxation, and liability regulations appropriate for UAM operations (Goyal et al., 2018; Murdock, 2021a; Ravich, 2021). Even industry stakeholders have different views and perspectives on these requirements (Murdock, 2021a, 2021b). Compounding these challenges is the concept of federalism, or federal preemption, whereby federal aviation regulations take precedence over local government regulations (Ravich, 2021). In addition, as the UAM ecosystem is yet to be implemented in actual communities, liability issues may also differ from location to location within the UAM ecosystem (NASA, 2020a). Collaboration and research are needed to solve federal preemption challenges relating to UAM operations (Ravich, 2021); there is a significant gap in the literature on this issue.

Eight Common Barriers: **Crosscutting Barriers.** The fourth NASA working group is the Crosscutting group assigned to investigate and develop guidance material, evolving industry standards, and other elements relevant to all the five pillars. These cross-cutting barriers are challenges that focus on safety, security, autonomy, affordability, and the NASA National Campaign and the NASA UAM Community Concept of Operations (NARI, 2021). Most of the published literature on UAM confirms that safety and safe operations are the critical enablers of public acceptance of UAM (Chancey & Politowicz, 2020; EASA, 2021a; Ellis et al., 2021; NASA, 2020a; Price et al., 2020).

Safety Considerations of Vertiport Operations

UAM Aircraft Safety Considerations

The traditional aviation safety performance we benefit from today represents over 100 years of lessons learned from incidents, accidents, warnings, and near misses (Helmreich & Merritt, 2019; Orlady & Orlady, 1999; Reason, 1990). Additional safety considerations for UAM operations that utilize a human pilot on board the aircraft will likely be similar to those in traditional aviation human factors such as pilot and controller decision-making, situational awareness, workload and task load management, loss of aircraft control, automation awareness, and management. It is also likely that marginal weather and environmental conditions will affect the safety of operations into and out of UAM vertiports.

For example, in 2019, a fatal helicopter crash in New York City highlighted the possible safety concerns and ramifications of UAM operations in a high-density city. In an Agusta A109 helicopter with one occupant, the pilot crashed onto the roof of a New York City building, causing a fire, destroying the aircraft, damaging the roof of the building, and killing the pilot. Probable causes of the accident included pilot decision-making, likely influenced by commercial pressure to complete the flight in a limited time frame, marginal weather, and subsequent loss of aircraft control due to spatial awareness. Both the human factors and environmental factors are documented as safety concerns for

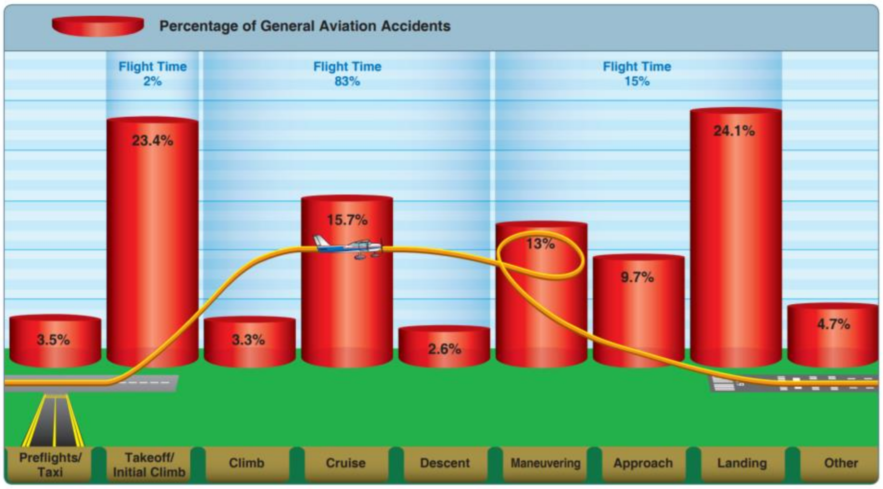
UAM vertiport operations (Namukasa et al., 2023). UAM operations without a pilot on board the aircraft [remotely controlled] will continue to have these human factors safety concerns; however, their characteristics will be different and likely more complex to understand (Bolstad et al., 2002; Cummings, 2011, 2014; Endsley, 2011; Namukasa et al., 2023). The 2018 white paper published by Uber Elevate proposed a targeted safety level for UAM operations to be twice as safe as driving a car per passenger mile and four times safer than flying in a general aviation air taxi operation under 14 CFR §135 (Uber Elevate, 2016).

The UAM target safety level implies that a UAM fatality would occur no more than 0.3 per million passenger miles, compared to today's current airline fatality rate of 0.13 (International Air Transport Association [IATA], 2021; Uber Elevate, 2018) and the current driver fatality rate of 1.2 per million-mile (NSC, 2021). Most aircraft accidents within the past 20 years have occurred during the flight's approach, landing, take-off, and departure from airports (Airbus, 2021; FAA, 2016; IATA, 2021). Considering that the most dangerous phases of flight are associated with arrivals and departures from airports, UAM operations will likely mirror similar trends, making operations from vertiport locations a critical area in which to focus safety research.

Figure 8 shows an illustration in the FAA's pilot handbook of aeronautical knowledge, showing the phases of flight and the percentage of accidents (FAA, 2016).

Figure 8

Percentage of Accidents per Flight Phase



Note. The accident percentage of flight time is indicated within each column. From *Pilots Handbook of Aeronautical Knowledge* by the Federal Aviation Administration, 2017, United States Department of Transportation. In the public domain.

UAM Vertiport Arrival and Departures. Traditional aircraft must demonstrate specific performance criteria to be certified by the aviation regulator. For example, in 14 CFR§ 23.2115, takeoff performance criteria include stall speed safety margins, minimum control speeds, climb gradients, performance with a sudden critical loss of power, aborted takeoff, and a net takeoff flight path gradient. However, eVTOL aircraft used for UAM are considered non-conventional or *special* aircraft class; therefore, many regulators have not established formal performance requirements for vertiport arrivals and departures (Goyal et al., 2020; NUAIR, 2020).

Although a common feature of eVTOL aircraft is the ability to take off vertically, some have *tilt-rotor* configurations that provide faster and more economical performance in the en-route flight phase (Kohlman et al., 2019; Sarsfield, 2019). However, the aerodynamic performance of these designs represents complex challenges; even similar designs in traditional aircraft, such as the Leonardo AW609 tiltrotor, still face significant latent performance hazards yet to be identified and tested (Aerossurance, 2016; Filippone & Barakos, 2020; Kohlman et al., 2019). In addition, critical consideration to protect ground assets and people will require UAM aircraft to conform to carefully designed final approach and missed approach performance, including typical and non-normal situations (Ancel et al., 2019), and community-friendly approach and departure profiles, such as noise abatement procedures, and environmental conditions (FAA, 2021a, 2021b; Kohlman et al., 2019; Patterson et al., 2021). However, eVTOL arrivals and departure performance criteria are not yet fully understood and tested (Filippone & Barakos, 2021; NASA, 2020a; NUAIR, 2020, 2021a; Price et al., 2020; Rajendran et al., 2021). The gaps in the literature within this area alone represent a significant challenge to safety.

Airborne Collision Avoidance Criteria. Safe flight in the UAM ecosystem will require aircraft to detect and avoid (DAA) or sense and avoid (SAA) other traffic to achieve accurate, timely, and predictive collision avoidance (Ellis et al., 2021; NUAIR, 2021a, 2021b; Pérez-Castán et al., 2020; Pongsakornsathien et al., 2020). All aircraft in the UAM ecosystem will need to demonstrate and be certified with this capability (Ramasamy et al., 2018). The FAA describes a possible interim path forward to achieving this by combining airworthiness requirements in various sections, including 14 CFR § 23, 25, 27, 29, 31, 33, and 35, and industry consensus standards (Goyal et al., 2018). In addition, EASA provides initial guidance on means of compliance (MOC) to facilitate certification for normal and critical performance failures (EASA, 2021c). However, there are significant gaps in the literature relating to the practical integration of DAA

(Filippone & Barakos, 2020; Stouffer et al., 2020; Stouffer et al., 2021), especially as it relates to UAM operations in and out of vertiports.

Vertiport Ground Safety. Operational density at vertiports is called *throughput*, and it includes the number of actual flights or passengers. A high-density vertiport is planned to have a throughput of 80 to 100 flights per day (NUAIR, 2021a). There are identified challenges with managing ground safety at each type of vertiport, including actual landing and take-off pad components, areas around the pads, and passenger egress systems (NAIR, 2020, 2021a). However, balancing the passenger experience with passenger safety requirements has not been fully explored in the literature, and there are no current standards or rules on vertiports (Goyal et al., 2018; NUAIR, 2020). In addition to regular throughput, vertiports offering maintenance, repair, and aircraft re-charging must ensure hazardous materials procedures, fire protection, and high energy [battery charging] hazards are managed (Anderson et al., 2017; Antcliff et al., 2016; Ellis et al., 2021; Schwab et al., 2021). Additionally, workforce skills, qualifications, and training for vertiport ground safety are yet to be explored (NUAIR, 2021a). These areas represent significant gaps in the literature, especially from the individual stakeholder perspective.

Vertiport Emergency and Contingency Planning. Traditional airports engage in regular emergency and contingency planning, including annual emergency drills as part of their auditable safety management system (Alexander, 2015; Brady, 2003; ICAO, 2013; Renner, 2001; Stolzer et al., 2015). Emergencies can include scenarios such as aircraft crash on or within the airport boundary, disabled aircraft on the runway, aircraft fire, cargo fire, ice, or contaminated runway resulting in aircraft overrun. In addition, there may be emergencies due to passenger or pilot health or security issues (Brady, 2003; ICAO, 2013). Although there is no formal guidance from ICAO or the FAA, it is expected that vertiport SMS will develop protocols evolved from traditional airports and heliport SMS (Ellis et al., 2021; NASA, 2020a; NUAIR, 2020, 2021a; Schwab et al., 2021). However, a significant gap in the literature examining how autonomy and human integration with that autonomy will factor into contingency and emergency planning for vertiport operations is among many other unexplored topics.

Passenger Safety. Studies by the FAA have revealed the people most vulnerable to being injured or killed by an aircraft propeller are the passengers as they are deplaning; in the years 1980 to 1989, 106 such accidents occurred, of which 29 were fatal (Collins, 1993). Passengers [people] can be particularly vulnerable in unfamiliar environments, particularly where heavy machinery and vehicles operate (Friend & Kohn, 2018). Many vertiports will be on platforms on urban structures like buildings and car parks, where egress and access could also present latent hazards to workers and passengers in addition to known workplace hazards (Friend & Kohn, 2018). However, few studies have examined or tested passenger safety protocols for vertiport operations.

Cargo Safety. Cargo delivery by passenger-carrying eVTOL aircraft is considered a possibility (German et al., 2018). Passenger-carrying aircraft usually have a cargo area separate from the passenger cabin and include rigorous safety precautions, including securing anchor points, reinforced flooring, fire suppression systems, and fire-retardant linings (ICAO, n.d.). For example, ICAO standards and regulations Document 10102 include the cargo compartments in the Boeing 737, 777, and 747 type aircraft with at least two independent fire suppressant systems certified by the regulator and dependent aircraft type. In addition, the forward cargo compartment on most passenger aircraft is heated and pressurized to transport animals, non-living human specimens (NLHS), living organs, and other organic matter (ICAO, n.d.). ICAO Annexes 6 and 18 prohibit dangerous goods from being carried even in the separate cargo compartment of a passenger aircraft (ICAO, n.d.). Given the small size of most eVTOL aircraft and passengers' preference for comfort and aesthetics (Ito & Furue, 2019), it is unlikely that cargo would have a dedicated space in a passenger cabin. There is a significant gap in the literature examining the safety implications of carrying cargo in the passenger cabin.

Dangerous Goods. ICAO defines dangerous goods as "Articles or substances which are capable of posing a risk to health, safety, property or the environment and which are shown in the list of dangerous goods in the Technical Instructions or which are classified according to those instructions" (ICAO, 2011, p. 1-1). The United States Department of Transportation (DOT) identified a total of 39 incidents involving lithium batteries in air cargo transportation between 2010 and 2016, resulting in smoke, fire, extreme heat, or explosion (DOT, 2019). In addition, lithium batteries passengers carry onboard that power passengers' portable electronic devices such as e-cigarettes, tablets, phones, and computers may also pose a hazard to safe flight (DOT, 2019; Laris, 2019; Thornburg et al., 2013). Passenger and cargo screening for dangerous goods is a consideration mentioned in the available literature; however, few studies have examined the stakeholders' concerns and opinions on managing these at vertiports.

Subsequent Literature

More recently, the NASA UAM Vertiport working groups and academia continue to move forward with research and development as this study progresses; therefore, this section tracks and summarizes the findings from emergent literature subsequent to the literature review and identifies new considerations, gaps, and any potential impacts on this study. In July, Mendonca et al. (2022) published a study in conference proceedings titled *Advanced Air Mobility Vertiport Considerations: A List and Overview* at the AIAA conference. This study focuses on the planning and deployment of vertiports, which identify factors including the location, design, regulations, safety, environmental impact, social acceptance, equity, and operational integration. These factors have been identified and discussed previously in this chapter; however, Mendonca et al. (2022) classify these known considerations into a formal framework. The research identified over 450 considerations from interviews with Subject Matter Experts (SMEs) participating in NASA's AAM Working Groups (AEWGs) in October 2021. The 450 considerations were grouped into 18 categories, forming a framework described by the authors as a "*living List*" [emphasis added] (Mendoca et al., 2022. p. 2) for continual development.

In addition to the living framework, the paper identified an increasing emphasis on State, Tribal, and Local Regulatory stakeholders. This grouping captures considerations related to state and tribal laws, local ordinances, regulations, and rules, directly impacting airport stakeholders, vertiport, and heliport management. The inclusion of this group as a stakeholder category in this study is therefore significant as it captures the current constraints and challenges these stakeholders are experiencing. As a result of this study and SME feedback, this stakeholder category called *Airport Management and Municipalities* was added to the sample frame for this project.

Gaps in the Literature

The purpose of this section is to expose the gaps in the literature relating to emergent themes of stakeholder perceptions on the operational safety of high-density vertiports. Although there is a growing amount of literature in this new field, few draw upon the expertise and perspectives of UAM stakeholders. Of the most notable are a high-level ConOps produced by NASA (NASA, 2020a; Patterson et al., 2021; Price et al., 2020), a detailed study by Booze Allen Hamilton (Goyal et al., 2018), and the work on vertiports by NUAIR (NUAIR, 2020a, 2020b, 2021). Again, however, significant gaps in both this focus and the broader UAM literature require investigation.

A comprehensive review of the current broad UAM literature substantiates gaps related to three broad topic areas: (a) regulations, (b) certification, and (c) automation. These wide topic area gaps are not isolated but cut across and influence every area of the UAM ecosystem, including airspace, aircraft, operations, and ground infrastructure. As UAM is a novel and emergent concept, the literature indicates that stakeholders have identified many known or apparent challenges and barriers to operating vertiports. However, few studies address *how and why* stakeholders perceive these challenges, their experiences, specific concerns and perspectives, and their preferences. These gaps are critical to understanding potential latent challenges that may be designed into vertiport safety systems. Understanding stakeholders' perspectives at a granular level will provide transparency on how they intend to prioritize, manage, and integrate their specific concerns and experiences toward planning for operational safety at high-density vertiports.

High-Level Gaps

Regulations, Regulators, and Governments. The literature has identified the challenges of developing regulations that govern, guide, and direct how and where vertiports operate (Filippo & Barakos, 2021; NUAIR, 2021). However, this literature leaves significant gaps relating to regulatory stakeholder perceptions at the local level, which will impact operational safety, especially concerning vertiplace size, access, location, parking, noise abatement procedures, regulations, and zoning. In addition, there is potential for hidden challenges relating to federal preemption for local, state, and tribal governments and the communities they serve. How local government stakeholders perceive UAM vertiport operations within their communities and their concerns, difficulties, perceptions, and experiences remain unknown.

Aircraft and Vertiport Certification. Certification of the eVTOL aircraft and the UAM vertiports they will operate from represents a significant gap in the literature. The current embryonic state of certification impacts every part of the UAM ecosystem and will particularly impact operational safety at UAM vertiports. Until industry consensus standards are published, certification will remain a significant challenge for every component of the UAM ecosystem, including arguably the most critical phase of flight, which includes take-off and landing from a vertiport. Stakeholders with technical expertise work with standards organizations to adapt and develop these performance criteria for eVTOL aircraft (Ferrell & Anderegg, 2020; Goyal et al., 2018; Kohlman et al., 2019; Moore & Goodrich, 2013; NASEM, 2020). However, little published literature focuses on these challenges from a detailed examination of stakeholder perceptions, concerns, beliefs, and operational or aircraft type preferences.

Automation Integration. There is considerable work underway examining UAM ecosystem automation, particularly integrating automation into the proposed IASMS, the safety system most UAM vertiport stakeholders will likely use (Ellis et al., 2021; Kopardekar et al., 2016; NARI, 2021; NASEM & ASAC, 2018). However, critical gaps in the literature invoke more questions than answers, for example, (a) what to automate, (b) how much [level of] automation, (c) when to automate, and (d) the level of human control and transparency of the system. All these challenges remain unanswered in the literature. Additionally, the literature points to the diversity of aircraft design types and the requirement for associated equipment to have uniformity in their functional and safety performance to be able to integrate with the UAM ecosystem and operate from vertiports

(Ferrell & Anderegg, 2020; NASA, 2020a; NASEM, 2020; Stouffer et al., 2021). Finally, no literature indicates UAM vertiport stakeholder perceptions or preferences of eVTOL design, such as location or number of propellers, doors, or emergency systems.

Additionally, as many eVTOL aircraft and vertiports are still in the test phase (Sarsfield, 2019), automated systems' safety performance and actual capabilities at UAM vertiports remain unknown (Fillipone & Barakos, 2021; McSwain et al., 2020). Moreover, stakeholders' perceptions of how the proposed IASMS aligns with their perceived safety needs, goals, and challenges are yet to be explored. For example, the current literature has not addressed stakeholders' perspectives on prioritizing, managing, training human actors, and integrating these systems.

Vertiport Facility and Service Gaps

One of the most significant gaps within the literature concerns how operations at high-density vertiports will integrate with the external UAM ecosystem and how they will operate internally. For example, challenges include vertiport design standards and preferences to support passengers and safe cargo movement, multiple aircraft parking, on-site maintenance, aircraft, and component charging, and multiple arrival and departures. There are no regulations, established best practices, formal guidance, or specific UAM vertiport standards to guide stakeholders in developing their systems to support safe vertiport operations. As there are no active passenger-service vertiports in operations at this time, the lack of standards and guidance is a significant challenge for UAM vertiport stakeholders. Existing standards are not appropriate for the emerging advanced eVTOL aircraft for UAM (FAA, 2021b; Stouffer et al., 2020). Simulations and controlled scenarios have primarily focused on UAS rather than UAM to identify potential hazards (Clothier et al., 2015b; FAA, 2020b; Hill et al., 2020; Pérez-Castán et al., 2020; Weibel & Hansman, 2004), but these do not specifically address vertiport operations. These studies also do not address stakeholder perspectives or preferences. Although the published literature presents an overview of the vertiport concept of operations, including a framework for the roles and responsibilities of stakeholders, there is no published literature on how stakeholders perceive, understand, or plan to implement operational safety in off-nominal emergencies. For example, the level of system transparency of the UAM ecosystem surrounding the vertiport safety system has not been adequately studied.

Departure and Arrival Gaps. The literature indicates that vertiport viability will depend upon high passenger and flight throughput. Therefore, vertiport operational safety will rely on advanced, automated, and integrated technologies connecting the aircraft, control centers, and the vertiports (Kopardekar, 2015; Pongsakornsathien et al., 2020; Syd Ali, 2019). Although studies have used dynamic modeling of UAM flights, this is a simulated UTM environment; therefore, calculating collision risks and traffic sequencing can only be estimated (Pérez-Castán et al., 2020; Pongsakornsathien et al., 2020; Ramasamy et al., 2018). Further, the FAA NextGen concept of UAM operations for the use of UAM corridors connecting vertiports (FAA, 2020b) has not been tested and is viewed by some as improbable within a high-density city environment (Filippone & Barakos, 2021; Stouffer et al., 2020; Stouffer et al., 2021).

In addition to the high-level technical challenges identified by academia and stakeholder publications, the NASA IASMS framework provides an outline for how stakeholders may work together in an integrated safety system (Ellis et al., 2021; Kopardekar et al., 2016; NARI, 2021; NASEM & ASAC, 2018). However, the literature does not explain or explore stakeholders' perceptions regarding their views, concerns, understanding, and preferences for how they will integrate proposed operational safety systems for high-density arrivals and departures at vertiports.

Passenger Handling, Experience, and Safety Gaps. Due to the lack of UAM passenger experience or simulation capability (Edwards, 2019; Filippo & Barakos, 2021), the current literature does not explain or examine stakeholders' perceptions or perspectives on factors that will have an impact on the passenger experience, especially when arriving, departing, or transiting through vertiports. Very few studies have examined passenger experience factors for eVTOL flights. For example, the cabin features such as handholds, door handles, and seat adjustments and flight factors such as pitch, roll, descent, and climb rates, aircraft performance in turbulence, noise, vibration, lighting, and passenger view remain unexamined (Edwards, 2019; FAA, 2021b; Kim et al., 2021). An example of a significant gap relating to passenger experience departing or arriving at a vertiport is *fear of heights*, which is surprising, as many vertiports will be located on top of buildings. In addition, few studies have investigated passenger reactions to vertical flight take-off, which is a considerably different sensation than taking off in a traditional aircraft. To date, there is no identified literature on how stakeholders will support the passenger experience of arriving and departing from vertiports by air. Stakeholders may not be aware that passenger unfamiliarity with the vertical experience may have implications for the safety and the acceptance of vertical flight.

Finally, safety and experience implications for the carriage, screening, and management of dangerous goods at the vertiport and on the aircraft have not been thoroughly examined within the literature. Few studies have examined stakeholder's perceptions, perspectives, and intentions on potentially hazardous items within the passenger cabin (Ito & Furue, 2019); this includes the location and securing of batteries required as part of the aircraft systems, propulsion, charging cargo, loading, and unloading, and passenger carriage of potentially dangerous goods.

Safety Management System Gaps. Aviation Safety Management Systems (SMS) are an established and effective system for mitigating risks and ensuring the safety of aviation operations. As urban air mobility (UAM) gains prominence, the application of a formal and fit-for-purpose SMS becomes imperative, particularly in the context of vertiports, the central hub for Vertical Takeoff and Landing (VTOL) vehicles (Ellis et al., 2021). However, the unique challenges associated with UAM operations, such as airspace segregation, automation integration, and proximity to densely populated areas, underscore the need for a comprehensive safety framework. While there is considerable effort into exploring how and what the UAM SMS will look like, there are no passenger carrying services or operational vertiports to identify real-time SMS performance.

The systematic approach of SMS, encompassing risk identification, assessment, and mitigation, proves essential in addressing these complexities. Noteworthy contributions to the literature on aviation safety management include the works of Reason (1997) on the Swiss Cheese Model and the International Civil Aviation Organization's (ICAO) Annex 19, which outlines the implementation of SMS in civil aviation; however, it is the work being done through the NARI working group that is producing the most comprehensive SMS guidance for UAM operations (Ellis et al., 2021). Incorporating an SMS at vertiports requires rigorous risk assessments, continuous monitoring, and proactive measures to enhance safety protocols. As with many of the other challenges represented by gaps in the regulations and literature, the accepted regulatory guidance on SMS does not cover UAM specifically; however, recently developed material for small uncrewed aircraft may provide the starting points for a UAM vertiport SMS. The currently published regulatory guidance includes the following examples: (a) FAA Order 8040.4, Safety Risk Management Policy; (b) FAA Order VS 8000.367, Aviation Safety (AVSSMS) Safety Management System Requirements, (c) FAA Order 8000.368, Flight Standards Service Oversight, (d) FAA Order 8000.369, Safety Management System, (e) FAA Order 1100.154, Delegations of Authority, (f) FAA Order JO 1000.37, Air Traffic Organization Safety Management System, and the (g) Air Traffic Organization Safety Management System (ATO SMS) Manual.

Theoretical Foundation

This chapter presented some of the core literature from the NASA working groups as a framework for a theoretical foundation. In addition, the broader literature on UAM, AAM, and Vertirports complements the core foundational literature focusing on UAM stakeholders, particularly those at the forefront experiencing the problem-solving efforts toward UAM challenges. Foundational literature from the NARI repository of studies indicates a framework of UAM integration barriers, previously illustrated in Figure 7, by the five critical challenge pillars and 24 barriers to implementation (NASA, 2020a; Patterson, 2021; Price et al., 2020;). Additionally, UAM stakeholders' roles and responsibilities were discussed in detail. This chapter presented gaps identified within this framework, primarily relating to understanding or explaining *how* and *why* stakeholders experience these challenges and how they shape their perceptions, reflections, and opinions. The phenomenological perspective is missing from the UAM stakeholder literature, as are emergent themes that may determine their decisions and interactions within the UAM stakeholder community (Freire, 1973; Heidegger, 2005; Higginbottom & Liamputtong, 2015).

Summary

This chapter discussed relevant and current literature on the emergent advanced aircraft industry and the concept of urban air mobility. The UAM concept is proposed as a new, safe, and efficient modality of transport for everyone in the community. However, this chapter critically examined the challenges and barriers to implementing this new transport modality, mainly related to the operational safety of vertiports. Gaps found in the literature are characteristic of a dynamic technology-driven concept, where regulation struggles to keep pace with innovation, and consumer experience plays a critical role.

Stakeholders, including academia, have identified high-level goals and outcomes for operational safety in the UAM and vertiport operations. However, there are significant gaps in the literature explaining how stakeholders are experiencing the challenges, perceptions, reflections, and opinions of safety system priorities and the levels of transparency and control of safety performance.

The next chapter presents the methodology for this study and why it was chosen as the most appropriate method to explore stakeholder perceptions when considering operational safety at vertiports. Next, the population, sample size, and strategy will be presented, along with the study design and analysis process. Finally, ethical considerations will be discussed in the development of the measurement instrument and the conduct of the research.

Chapter III: Methodology

This chapter explains the chosen research methodology and discusses the characteristics of qualitative observational research. The rationale, justification, and advantages of choosing non-experimental qualitative research over other methods are discussed, including why these methods are most appropriate to answer the questions about exploring and understanding a homogenous community. In this study, the community of interest is the individuals who work for stakeholder organizations actively participating in the challenges associated with the safe operations of UAM vertiports. This chapter also outlines the data collection process, including the design, instruments, and procedures, with enough detail to reproduce the study, including the ethical considerations.

This chapter further discusses qualitative research concepts, including (a) credibility, dependability, reliability, and transferability; (b) triangulation and mitigation of researcher bias; and (c) how these concepts are applied for rigor and repeatability of the study. This study examines the research problem through a plurality of qualitative perspectives: narrative and phenomenological. These two perspectives combine to support highly contextual data rich with sentiment and affect, providing a unique theoretical contribution in addition to the practical contribution gained from a more comprehensive, multi-dimensional examination of emergent themes and perspectives of UAM vertiport stakeholders. Finally, the chapter concludes with a summary of critical elements of the methodology and design and how they apply to interpret the results in the next chapter.

Research Method Selection

Qualitative research is a powerful, dynamic, non-linear process with central core principles of collaboration, criticality, reflexivity, and rigor (Bazeley, 2013; Bazeley & Richards, 2000; Ravitch & Carl, 2016). Qualitative research with a narrative perspective can identify contextual meaning and explain hidden themes and factors in complex problems, such as gender bias (Lamb & Winter, 2021) and aviation safety issues (Lamb et al., 2020). In comparison, qualitative research with the phenomenological perspective can explain and give meaning to human perceptions, behavior, decision-making, and experiences during periods of change such as the COVID-19 pandemic (Lamb et al., 2020). This study uses qualitative non-experimental exploratory research with narrative and phenomenological perspectives, leveraging *affect* (emotions) and *sentiment* to draw out emergent themes (Creswell & Creswell, 2018; Higginbottom & Liamputtong, 2015).

Urban air mobility and the vertiport are emerging concepts within the advanced aviation ecosystem, residing in the future realm with operations yet to be realized from the conceptual framework into operational reality. Furthermore, the literature reveals a lack of explanation and understanding relating to the cohesion of stakeholder needs, perspectives, and experiences working towards safe vertiport systems. These stakeholder perspectives will likely influence safety system design interfaces, processes, standards, regulations, and interactions. Therefore, choosing a qualitative observational methodology supports deep and comprehensive exploration and understanding when faced with the phenomenon of future realm challenges, especially those driven by human experiences and behavior. A rigorous explanation and understanding of the *how* and *why* of stakeholders' perspectives is the foundational premise for developing and interpreting quality variables for future quantitative or mixed methods research.

Research Approach

Non-Experimental Exploratory Research. UAM and vertiport operations are emergent and novel, and much is unknown, untested, and unexplained (Filippo & Barakos, 2021; Stouffer et al., 2021). At the same time, many challenges and barriers to UAM implementation have been identified (NASA, 2020a, 2020b; NUAIR, 2020, 2021a, 2021b; Patterson et al., 2021; Price et al., 2020; Reiche et al., 2019; Rice et al., 2020; Winter et al., 2020). However, there is little understanding or explanation of *how* and *why* stakeholders perceive these factors, and more importantly, how these experiences may govern their behaviors, decisions, and interactions, and what additional unknown themes await to emerge. Therefore, qualitative research, particularly non-experimental exploratory methods, is highly appropriate to explore and understand the "how and why of systems and human behavior and what governs these behaviors" (Edmonds & Kennedy, 2017, p. 141-142). Therefore, the most appropriate research method to answer the research questions is this qualitative approach, with a focus on the phenomenological perspective. The core purpose of this study is to discover new emergent themes and explain and understand UAM vertiport stakeholders' perceptions, opinions, and decision-making within the phenomena of the conceptual framework of the impending reality of UAM vertiport operations.

The Narrative Perspective. In qualitative research, "The narrative approach involves gathering information in the form of storytelling by the participant to understand a phenomenon" (Edmonds & Kennedy, 2017, p. 160). This study asks open-ended questions encouraging participants to provide narratives, descriptive examples, and stories of how they are approaching, feeling, and experiencing working through the daily challenges and barriers associated with their work in this emerging and unique industry.

The narrative perspective of inquiry supports capturing context through thematic analysis, providing the basis for primary and secondary code generation (Bazeley, 2013; Bazeley & Richards, 2000).

The Phenomenological Perspective. Phenomenology is both a philosophy and a research method focused on an individual or group's lived experiences of a phenomenon (Ravitch & Carl, 2016). A phenomenon is not limited to a fixed event, time, or space; one example is the phenomenon of parenthood or being an elite athlete. The phenomenon can be any sensations, perceptions, or consciousness that arise from experience with specific phenomena, and how the essence of the experience includes the *what*, *how*, and *why* participants experienced or are experiencing (Creswell & Poth, 2018; Edmonds & Kennedy, 2017; Ravitch & Carl, 2016). In this study, the phenomena are the human perceptions, experiences, and opinions of solving a complex future realm challenge. Additionally, measurements of *affect* (emotions) and the magnitude of *sentiment* (negative, very negative, and positive, very positive) were used to gain deeper context to the participant's experiences.

Combining Narrative and Phenomenological Perspectives. Both perspectives of qualitative inquiry used in one study offer unique and comprehensive benefits for constructing deep meaning and understanding of complex phenomena (Patterson, 2018), such as the impending operational reality of the conceptual UAM vertiport or any focused advanced aviation operation. The benefits of using these two methods of inquiry combine to support the hermeneutic design philosophy (Creswell & Poth, 2018; Ravitch & Carl, 2016), which focuses on the reflective interpretation of the human experience (Edmonds & Kennedy, 2017; Patterson, 2018; Ravitch & Carl, 2016).

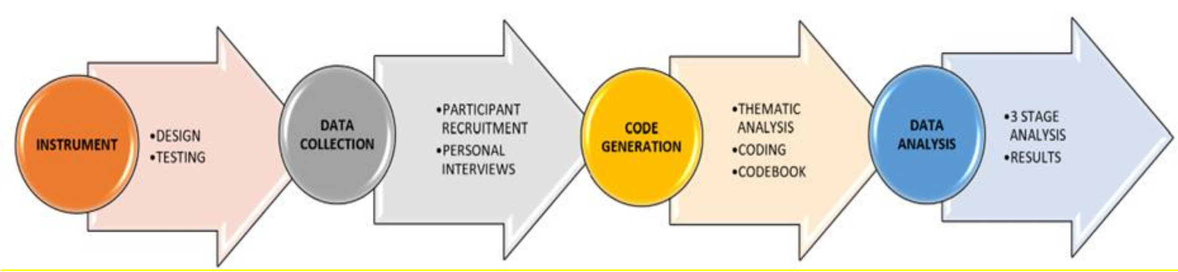
Together, the narrative method of inquiry enabled the construction of unique codes and sub-codes within the data providing context, while the phenomenological inquiry supported exploring and identifying emergent themes within the homogenous group's lived challenges, perspectives, and experiences. The plurality of both approaches supports the exploration of deeper meaning within complex phenomena of the specific lived experience, exposing common and previously undiscovered universal themes within a homogenous group at an allocated point in time (Dall Alba, 2009; Koro-Ljungberg et al., 2013; Patterson, 2018).

Research Design

There were four phases in the design of this study. The first phase used the literature to design the instrument, which was subsequently refined from two pilot studies and input from three subject matter experts, a qualitative research professor, and the dissertation committee. The second phase focuses on participant recruitment and the personal interviews to collect the data. The third phase generated the codes and codebook from the thematic analysis, while the fourth phase was a compressive three-stage process of data analysis and production of the results. Figure 9 below provides a diagram of the research design.

Figure 9

Four-Phase Study Design



Phase One of Four. The first phase consists of the initial instrument design based on the available literature focusing on vertiport operational safety. The primary researcher designed the instrument, which consisted of 18 open-ended questions, of which six were the actual research questions derived to elicit highly contextual answers to support answers to the central research question of the emergent themes; a copy of the instrument can be found in Appendix C. Three UAM vertiport stakeholder volunteer experts reviewed the instrument; then, a pilot study was conducted. Subsequently, the instrument was further critiqued and refined by feedback from the dissertation committee and a qualitative subject matter expert. A second pilot test revealed the instrument was highly effective at gaining the rich data required; it provided detailed and highly contextual answers to each of the secondary questions, as well as showing the overlap in contexts for potential code generation; these consistent data included inferences to commercial pressure, safety culture, education and outreach, which were eluded to in the first pilot test, however, not as effectively as in the second pilot test. Of primary importance according to qualitative research methodology (Creswell & Miller, 2000; Bazeley, 2013), the data provided enough context to support answers to the research questions and the main central research question relating to the emergent themes. SMEs, the qualitative professor, and the dissertation committee. Although from the sample population, the SMEs were not included in the sample frame of participants. The purpose of using SMEs was to ensure the instrument's qualitative reliability, which is described as *confirmability* and *transferability* (Creswell & Creswell, 2018; Ravitch & Carl, 2016; Tesch, 2013). Using independent SMEs provided a different lens of interpretation through reflexive dialogic engagement, supporting the opportunity to contrast and test the robustness and context of the instrument (Creswell & Creswell, 2018). In the context of this study, using the independent SMEs, the independent coders, the independent qualitative research professor, and the leveraging the perspectives of the dissertation committee are practical strategies to support the overall quality of the study, including transferability and repeatability. The responsibilities of the SMEs were to (a) review and refine the instrument, (b) assess the applicability of each question, (c) provide feedback and suggestions, and (d) conduct a final critical reflexive review of the instrument. The instrument design corresponds directly to aspects of the central research question and assists the independent coders in developing and leveraging a comprehensive set of codes and subcodes that were categorized into emergent themes from the UAM stakeholders' perceptions, experiences, and opinions. Each reflexive question within the instrument effectively drew on these perceptions and reflections of problem-solving, decision-making, and the perception of other stakeholder individuals [peers] involved in the same challenges [assumptions] and decision-making. The developed instrument is contained in Appendix C. The alternations to the instrument included minor language refinement and the additions of the study's actual research questions as instrument questions. Alterations and iterations of the instrument are recorded in the master researchers log (MRL).

Phase Two of Four. Phase two of the study involved participant recruitment and personal interviews using the semi-structured instrument of open-ended questions to support rich, thick, reflective answers from each participant (Bazeley, 2013: Bazeley & Richards, 2000). The target sample frame was five participants from each of the four stakeholder categories: Original Equipment and Aircraft Manufacturer (OEM), Federal Government and Academia (Gov), Research and Development (R&D), and Municipalities and Airports (MUN). Individual interviews were conducted in each category, and data saturation was assessed as adequate with the planned number of participants in each of the categories; concurrently, the audio recordings from the teams calls were transcribed into PDF documents. Once the interviews were all completed and transcribed, they were distributed to the three independent coders for review and further consideration of codes and subcodes. The completion of the interviews and distribution to the independent coders signified the end of phase two.

Phase Three of Four. Phase three involved an iterative thematic analysis and coding of the data by the independent coders. The independent qualitative coders were chosen for their recent experience and knowledge of qualitative research within the doctoral program at Embry-Riddle Aeronautical University. Additionally, these coders also had a fundamental understanding of the emerging advanced aviation and the UAM vertiport concept; as recent graduates of the doctoral program, the coders also have a solid grasp of aviation-related safety systems. Three independent coders conducted an initial thematic analysis to establish codes and subcodes from the narrative perspective. The primary researcher hosted and conducted several coding meetings where the codes and themes were discussed and refined. After several meetings, the further iterations of a thematic analysis involved examining the data from the phenomenological perspective to extract deeper layers of codes and sub-codes. Subsequent iterations and coding were conducted, and a total of three coding meetings took place; the final meeting concluded, and the independent coders each contributed their summary of the codes to the researcher and committee chair. The outcome of the three independent coders resulted in a comprehensive codebook consisting of a code hierarchy and a highly transferable coding framework for the primary researcher's final coding and data analysis. The deeper analysis is discussed later in the chapter.

Phase Four of Four. Phase four of the study is a comprehensive process for data analysis by the primary researcher. Phase four used the codebook and code hierarchy for further thematic analysis processes; during this phase, a couple of code descriptors in the codebook were expanded upon and clarified to encompass a clearer meaning, for example, the code *security*, which the coders understood as physical and cyber security was clarified as both in the code book definition. Additionally, the primary researcher added sentiment coding, which the independent coders inferred from the transcripts and the primary researcher observed when conducting the personal interviews.

Phase four was characteristic of most qualitative research; it was time-intensive and required comprehensive reiteration and triangulation to capture meaning from the deep analysis of coded data. Phase four followed the data analysis process map outlined in Chapter V, which clearly shows the four phases of the study design, expanding upon phase four. Finally, the notes and evolution of the instrument and coding process are outlined in this dissertation and the researcher's master research log, which contains the memos, notes, journal entries, and data models through each phase of the study to capture the challenges and reflexive rationale behind the challenges and changes. A copy of the excerpts from the master research log is located in Appendix B.

Population/Sample

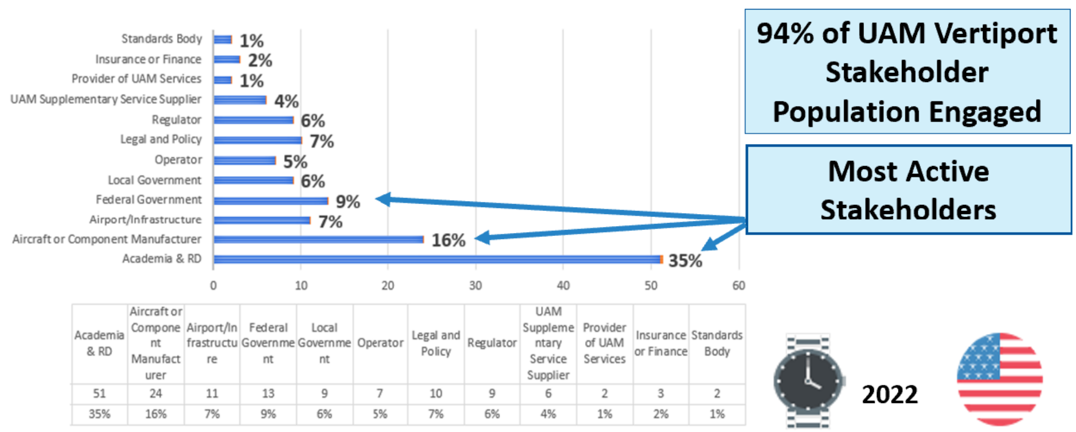
The population of interest in this study is stakeholders who are actively working or directly involved in one of the four UAM vertiport stakeholder groups: (a) research and development, which includes academia; (b) the federal regulatory bodies and (c) aircraft component manufacturers, (d) Airports and Municipalities. These four stakeholder groups include organizations with a direct or indirect role and responsibility in UAM and vertiports in the United States, and that responsibility flows to the individual roles within their stakeholder organizations. Not all of these stakeholders plan to be involved in the daily operations of vertiports. However, they directly and indirectly influence operations: AAM and UAM Vertiport policy, aircraft certification, vertiport infrastructure, aviation insurance, legal issues, aviation-related human training and resources, and aircraft product and service development.

In addition, stakeholders in UAM vertiports currently play an active role in industry problem-solving through their participation in AAM and UAM working groups, academia, or other collaborative forums working on UAM vertiport challenges and barriers. Several notable industry research efforts have gathered stakeholder data from the general UAM stakeholder population involved in these activities. These efforts have also involved conducting interviews and working groups, and from these efforts, the documents reveal the characteristics of the general population of interest in this study. The literature includes (a) the Booz Alan Hamilton industry report (Goyal et al., 2018), (b) the NUAIR vertiport trade study and vertiport software study (NUAIR 2020, 2021b), and finally, (c) the NASA working groups focusing on the identified challenges and barriers (NARI, 2021; NASA, 2020a, 2021a). Each document lists the contributing stakeholders. Therefore, this is the list from which the participants were selected for personal interviews for this study, which represents the larger population of the emerging advanced air mobility industry, specifically those focused on UAM vertiports.

The list of actively engaged stakeholders is presented in Figure 10, which captures the results of the literature analysis (Goyal et al., 2018; NARI, 2021; NASA, 2020a, 2021a; NUAIR, 2020, 2021b). The resultant list indicates that the most active stakeholders are from the following groups: (a) academia, research and development, (b) the federal government, and (c) aircraft or component manufacturers. However, during the instrument refinement by the volunteer subject matter experts, the participant categories were refined to include Airport and Municipalities. Therefore, this study's sample frame focuses on individuals from these four most active groups from 2018-2022. The NASA concept of operations outlines this era in UAM development as a UAM maturity phase aiming to achieve ULM level four as stakeholders grapple with solving the immediate and foundational challenges of transitioning from theoretical concepts into practice.

Figure 10

UAM Vertiport Stakeholders Participating in Industry Problem-Solving



Academia & RD	Aircraft or Component Manufacturer	Airport/Infrastructure	Federal Government	Local Government	Operator	Legal and Policy	Regulator	UAM Supplementary Service Supplier	Provider of UAM Services	Insurance or Finance	Standards Body
51	24	11	13	9	7	10	9	6	2	3	2
35%	16%	7%	9%	6%	5%	7%	6%	4%	1%	2%	1%

Note. The graph shows twelve stakeholder groups that have participated in notable industry studies and ongoing NASA working groups. The sample frame focuses on the top few, and a local categorization resulted in identifying four UAM stakeholder groups most active in the problem-solving efforts.

Sampling Frame

Selecting a sample frame of stakeholders dealing with the primary and most immediate challenges to realize UAM vertiport operations posits a logical and sound strategy for sample frame choice to answer the research questions. According to the data gathered in the literature review, the stakeholders with the most negligible participation in the industry efforts at the time of this research were the standards bodies, insurance and finance organizations, and supplemental service suppliers. Despite the importance of their roles in the UAM and vertiport ecosystem, these less active stakeholder groups are likely waiting for solutions to the immediate challenges and barriers before solving challenges relating to their groups. Examination of this literature indicated the participation of approximately 94% of the assessed general UAM vertiport community, representing the stakeholders most likely to be directly involved in solving immediate challenges and barriers to realizing UAM vertiport operations. Therefore, Table 1 presents four stakeholder categories that appear to be the most active in UAM vertiport problem-solving efforts.

Table 1

The Four UAM Vertiport Categories and Target Sample Frame and Size

Stakeholder Category	Organization Examples	Target Sample Size [a]
1. Research & Development	NUAIR, AIAA, Aurora, ASSURE, HAI.	5
2. Federal Government	FAA (Next Gen, UAS, Vertiport), DOT, DOJ, NASA, NARI, NTSB.	5
3. Aircraft Component Manufacturer	Embraer [Eve], Airbus, Hyundai [Supernal], Boeing [Wisk], Joby.	5
4. Airport Management & Local Municipalities	Existing airport management, Local Municipalities (e.g., Oklahoma City, & Choctaw Nation, LA county, etc.)	5
	Total Participants	20

Note. Sampling continued until the target sample size was achieved in each category and saturation was achieved. Some aircraft component manufacturers are also UAM operators.

Sample Size

Unlike quantitative research, minimum sample sizes depend upon data adequacy (also called data saturation) and achieving highly contextual answers to the research questions; additionally, a characteristic of qualitative research is *particularity*, meaning the perceptions of an individual are particular to their perceptions, reflections, and opinions (Creswell & Creswell, 2018; Green & Caracelli, 1997; Gibbs, 2007; Ravitch & Carl, 2016). Therefore, in qualitative research, the sample size should be considered, emphasizing *transferability*; gaining highly contextual answers to the research question can only be achieved by reaching data adequacy, also called data saturation (Morgan, 1996; Morse, 1995, 1998; Patton, 2015). The sample size required for this study was determined by the results of the successful pilot study, which indicated the instrument would provide a thorough and rigorous answer to the research questions and provide a multi-perspective contextual understanding of the problem (Ravitch & Carl, 2016). The researcher can assess the progress toward the goal of answering the research questions by recognizing the point of saturation in the data collection. The point of data saturation is evaluated by the ability to draw answers to research questions from the data set, which may be from one participant or many, depending upon the type of research and research design (Patton, 2015). Adequate saturation is achieved when similar and logical themes and codes emerge within the participants' answers and repeatedly appear across all the participant data. The sample size for narrative and phenomenological research philosophy directly applies to this qualitative research design (Creswell & Creswell, 2012; Higginbottom & Liamputtong, 2015; Jagosh et al., 2012). However, this sampling quota was purposeful to ensure the representation of the participant roles and categories that supported transferability and generalization to the current UAM Vertiport stakeholder community. This sampling strategy focused on an expert sample of professionals in a dynamic and emerging industry that are proactive in industry working groups, therefore, the expectation of data saturation and gaining meaningful explanations of the context, including comprehensive answers to the research questions, was assured.

Sampling Strategy

Qualitative research uses sampling techniques most likely to support context-rich and detailed data from the population of interest. Thus, researchers deliberately select individuals based on their specific or unique ability to provide valuable insights and meaning to the problem. This strategy is *strategic* and *purposeful*, also called *purposive* sampling (Ravitch & Carl, 2016). In this study, purposive sampling was the most appropriate method to answer the research questions, while this strategy is also considered a primary sampling strategy in qualitative research (Coyne, 1997; Patton, 2015).

The researcher specifically selected participants because they have specialized roles and responsibilities as UAM vertiport stakeholders. Additionally, by the nature of their position, each also has highly specialized knowledge, qualifications, and experience in dealing with UAM vertiport safety, and thus, with the primary research problems in this study; in qualitative research, this also means that they share a *common unit of analysis* (Patton, 2015; Ravitch & Carl, 2016).

Data Collection Process

The primary data source for this study was the transcribed audio recordings of the participant interviews. The researcher also generated secondary data and records outlined in Chapter IV and the master research log to support the study's repeatability and credibility. The MRL includes the data captured from researcher memos, researcher reflections, coding notes, and data models (Ravitch & Carl, 2016). The primary function of the MRL was to provide an additional mechanism to boost the rigor, quality, and credibility of the study by (a) enabling multiple perspectives for instrument testing and refinement, (b) supporting Tesch's coding strategy researcher reflexivity, (c) providing a repository for validity strategy notes, and (d) supporting context related to the study design to aid repeatability. The data collected for the MRL was directly entered into a Microsoft Excel spreadsheet, discussed in detail later in this section.

The central apparatus for data collection was personal interviews, which were audio-only recordings from either telephone or a virtual meeting platform. The audio recordings were captured as a voice-only audio file (MP3 format) and manually transcribed by the researcher into a Microsoft Word document, following the Embry-

Riddle Aeronautical University (ERAU), Internal Review Board (IRB) -approved protocols for this study, detailed later in this chapter. In addition, the researcher and SME generated data for instrument development, which was captured by email, and changes were tracked from draft documents and notes from discussions. Excerpts from the MRL are located in Appendix B.

Design and Procedures

The design of this study uses a strategically sequenced iterative four-phase process. This design supports the instrument test and refinement, leveraging the experience and feedback from the dissertation committee members, an additional qualitative research professor, three volunteer subject matter experts from the population of interest, and three independent volunteer coders, each with recent experience in qualitative research at the doctoral level.

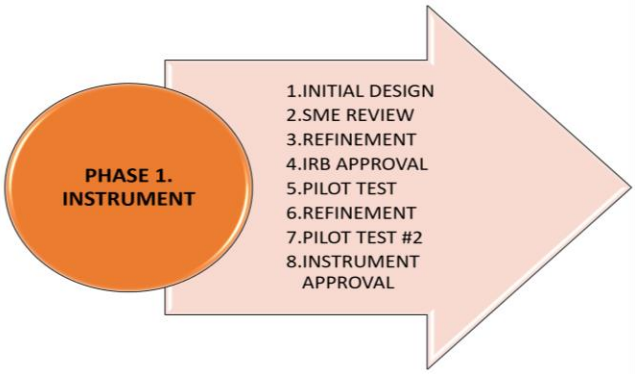
Participant recruitment did not commence until after the instrument was assessed to be highly reliable, confirmable, and transferable. The participants, all purposefully sampled, were active within the industry forum working groups connected with the NASA NARI working groups; however, all were active in other forums like those run by the Vertical Flight Society, Helicopter Association, and the standards bodies working groups. The participants were invited to participate in the personal interviews via email and personal outreach through the working group networks. Phase three was dedicated to iterations of the thematic analysis in conjunction with the three independent coders' iterative coding and code hierarchy design. The three independent coders conducted their work independently and then discussed the results collaboratively at three coding meetings to support coding reliability and minimize researcher bias. Then, the primary researcher performed the final analysis in the qualitative data analysis program NVivo, a power platform for analyzing participant cases, codes, and subcodes that allows for identifying data patterns, frequency, and the magnitude of sentiment to identify emergent themes. Phase four data analysis was comprehensive and detailed; further discussion and a process map for the phase four analysis are presented in chapter four of this dissertation. This process map supports the replicability of the study design.

Phase One: Instrument Design Test. The first phase of this study involved thoughtful instrument design from the literature and discussions with the three volunteer industry SMEs. The first pilot test was conducted on a volunteer participant; the results were analyzed, and then, with the assistance of the dissertation committee and a volunteer qualitative research professor, suggestions were offered to refine the instrument further. A second pilot test of the instrument revealed highly contextual data from the transcript, with clear indications the instrument was highly effective at gaining insights to answer the research questions.

The pilot testing and refinement of the instrument was a critical step with the following purposes: (a) ensuring the *quality*, *transferability*, *reliability*, and *relevance* of the instrument and (b) aiding the researcher in identifying and mitigating researcher bias. Therefore, phase one of this study was a critical foundation for establishing the study's quality elements. The final instrument used in this study is located in Appendix C. The supportive notes regarding instrument development and refinement are located in the MRL. Figure 11 presents the additional procedures within phase one.

Figure 11

Additional Procedures within Phase One: Instrument Design and Test

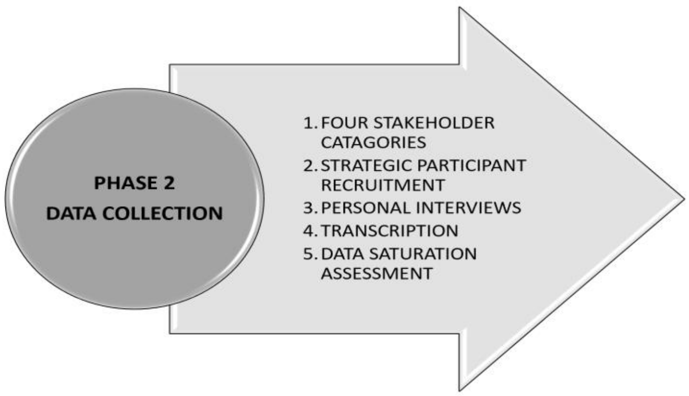


Note. The master research log captures supportive notes, memos, code changes, and data models during the study phases. Additionally, the MRL serves as an auditable process map for study repeatability.

Phase Two: Participant Recruitment and Interview. The researcher invited individuals from the four UAM stakeholder categories through two main communication channels: (a) a personal invitation through email and (b) a notice through the NARI portal. Only participants actively participating in the problem-solving challenges for UAM vertiport safety consistent with the stakeholder characteristics presented earlier in this chapter in Table 1 were eligible to participate. The participants were interviewed at a time and method convenient for them. The interviews were all conducted using a virtual meeting platform (Microsoft Teams). Only the audio data was recorded; however, much like interviews conducted in person, the researcher and participant could see each other. The interview questions consist of 18 open-ended questions and 10 demographic questions. The audio from each interview is transcribed into a Microsoft Word document, saved as a PDF file, and distributed to the volunteer coders. Figure 12 illustrates the procedures within phase two of the study design.

Figure 12

Procedures within Phase Two: Participant Recruitment and Interviews

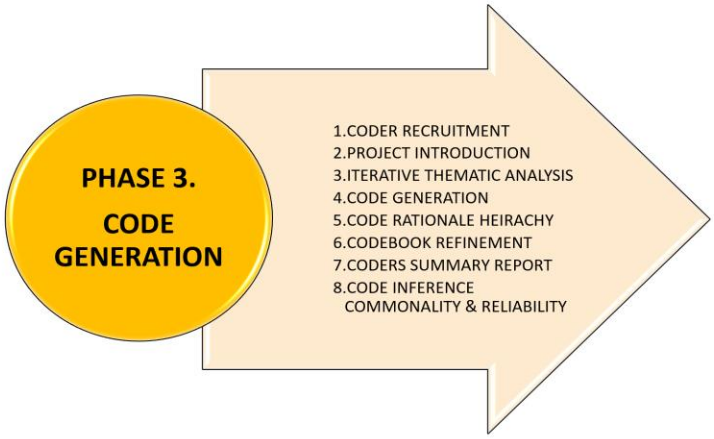


Phase Three: Thematic Analysis, Coding, Concurrence of the Code Hierarchy (Codebook). Once the twenty interviews had been completed, the de-identified transcripts were distributed to the independent coders. The coders were selected for their experience with qualitative research and fundamental knowledge of the UAM vertiport research efforts. Additionally, the coders all had valid ERAU IRB human subject research approval at the time of coding. Recruitment of the volunteer coders was achieved through a verbal invitation through the ERAU College of Aviation Ph.D. program. A formal invitation outlining the purpose of the study and coder directions was sent through email with the dissertation chair in copy in all correspondence with the coders regarding the project. Each coder completed the initial thematic analysis prior to the first formal coding meeting, and the transcripts and initial codes were discussed to ensure each coder understood the UAM vertiport operational safety context and purpose of the study and that any questions or concerns were addressed. The initial coder meeting ensured the coders were aligned on the high-level purpose of the study and an understanding of the research questions. The Dedoose Qualitative Data Analysis Tool was used for this purpose, as it is user-friendly and low-cost compared to NVivo. Three coding meetings took place, providing an iterative layered approach to developing the code hierarchy. As there was no established theory on which to build specific codes, inter-rater reliability was determined by identifying consensus and overlap of the code categories (hierarchy).

Additionally, each coder independently submitted a summary of their interpretation of the data and codes through an email report. The three coders and primary researchers also assessed data saturation. Data saturation was indicated by reoccurring patterns with the codes and sub-codes, enabling emergent themes to become apparent, and preliminary answers to the research questions could be explained (Morse, 1995, 1998). Once data adequacy was achieved, participant recruitment ceased to avoid *oversaturation.* Oversaturation in qualitative research represents waste and redundancy (Morgan, 1996). Additionally, the three coders agreed on coding consistency and confirmability (Creswell & Creswell, 2018; Creswell & Miller, 2000). If data saturation is not achieved in future studies, it is recommended that participant recruitment continue, or the robustness of the instrument may need to be refined.

Figure 13

Procedures within Phase Three: Code Generation

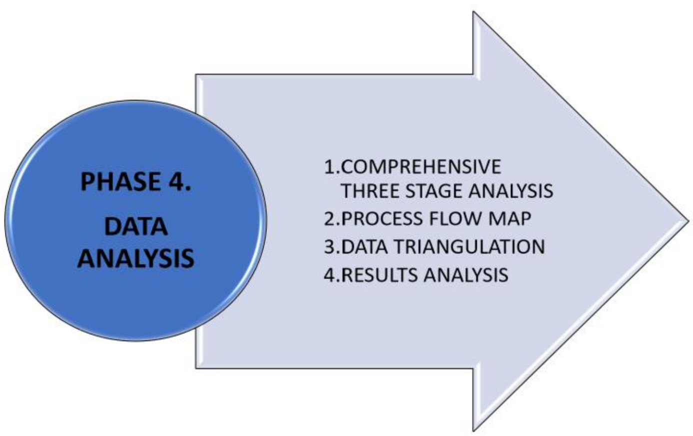


Phase Four: Final Development of Themes and Factors. The final phase of this study was comprehensive and detailed, involving recognized processes combined into a unique method to capture the plurality of the narrative and phenomenological perspectives. As the data analysis in phase four developed through the analysis processes outlined in Chapter IV, the highly contextual answers to the research questions were revealed, and data patterns and relationships emerged. This phase involved drawing inferences from the results through a deeper data analysis using the powerful qualitative data analysis NVivo platform and interpreting the data. Additionally, this phase drew comparisons and connections to existing literature and established theories. This final phase of the study yielded surprising results in the level of detail supporting the identification of three main emergent themes. The results provided the framework for the discussions and conclusions on the practical and theoretical implications for further research and highlighted opportunities for further investigation, detailed in Chapter V.

NVivo Analysis. Following the establishment of a robust codebook, the primary researcher conducted a deeper comprehensive analysis of the established codes' cross-case/cross-code using analysis processes in NVivo and Microsoft Excel. The investigation processes included matrix code analysis, Boolean matrix intersections, matrix cooccurrence, data visualization through concept mapping, code frequency through word clouds and histograms, code and sub-code hierarchy matrices, and dendrograms. From these deeper secondary analytical processes, the researcher-generated data model was compared with the NVivo generated conceptual model cluster concepts as patterns in the data emerge to represent themes (Bazeley & Richards, 2000; Fofana et al., 2020).

Figure 14

Procedures within Phase Four Data Analysis



Apparatus and Materials

In this study, apparatus and materials refer to the equipment used to collect, store, and analyze the study's data. This equipment falls into three categories: (a) technical equipment, (b) tools, and (c) testing instruments. This section provides the details of each equipment category and the rationale and explanation for the choice.

Technical Equipment. The technical instruments used in this study were a voice recording device, a virtual meeting platform, and a mobile phone. The tools used were a qualitative research coding software platform and the Microsoft Word® and Excel® applications on the researcher's laptop computer. Finally, the testing instrument was the personal interview questionnaire for the personal interview. These apparatus and materials were assessed as the most appropriate for the design, which, from the equipment perspective, can be divided into two separate functions—materials and equipment for the master research log and the materials and equipment for analyzing the participant data.

Master Research Log. The format of a master research log for qualitative research can vary; the primary functions are to track changes and modifications to the data plan and instruments and collect opinions, feedback, and input from the subject matter experts. The MRL also records the researcher's journal notes, memos, reflections, and experiences (Ravitch & Carl, 2016). Data was input into the MRL from many sources: phone conversations, email exchanges, track changes on the draft dissertation, and exchanges between the researcher and SMEs regarding instrument development. The date and source of all notes are recorded in the MRL notes sections. The data collected and recorded in the MRL is part of the critical function of supporting reflexivity and ensuring the credibility and quality of the researcher-generated data. Therefore, to achieve maximum cross-referencing and analysis, the MRL in this study used Microsoft Office Home and Student 2016 Excel (Version 2112). The subsequent analysis used the qualitative data analysis software (CAQDA) NVivo 12-Pro and the cloud-based Dedoose software discussed further in the tools section.

The MRL Excel consists of multiple-colored tabs. The main spreadsheet tab included the following columns: the date of the entry and the MRL element (memo, reflection, coding, theme). The primary elements of MRL categories use a drop-down box feature to select the relevant sub-section. The rationale for the drop boxes is to divide the researcher's data entries into categories for easy repetition of the study's process. The MRL categories and subcategories format are shown in Figure 13; the drop-down box options are exposed in the figure.

Figure 15

Master Research Log: Main Page of the Microsoft Excel® Spreadsheet.

	A	B	C	D
1	**Date**	**MRL Element**	**Narative Content (Change/Challenge/Issue…)**	**Post reflective notes**
2		Memos		
3		Reflection		
4		Coding		
5		Theme		
105				

MRL Legend | MRL main Page | 9 Validity Tools | NASANUAIRStakeholder List | Data Models

Equipment for the Participant Data Collection. The data were collected via audio recording for the phases involving participant action (three and five). The researcher's Apple's sixth-generation iPad 2 (voice recording app) is the most efficient recording device, with software version 15.1 that records the audio from interviews and phone discussions in MP3 format. The researcher's computer was used to convert the audio file into text format on the researcher's computer. All the devices used by the researcher, including the cell phone, iPad, and laptop, require independent passcode and user identification to access, ensuring the security and confidentiality of study data.

Research Tools. The tools used for analyzing participant data were (a) the Dedoose collaborative qualitative data analysis software and (b) the NVivo 12-Pro, a computer-assisted qualitative data analysis software (CAQDA) for qualitative data coding and thematic analysis. The Dedoose software is low-cost and user-friendly for researchers. The NVivo software integrates Microsoft Word and Excel applications for the CAQDA, and all documents were uploaded and managed on the researcher's secure laptop computer. The researchers' computer is a Dell Inspiron 7306, with an 11^{th} Generation Intel Core i7-1165G7, 2.8GHz processor, and 16.GB ram. The Microsoft Windows program uses Version 11 Home, 21H2.

Testing Instruments. The testing instrument was the personal interview questionnaire. The notes from the instrument's pilot testing are captured within the MRL and are located in Appendix B, while a copy of the instrument can be found in Appendix C. The materials and apparatus were chosen based on the researcher’s experience using the NVivo software program; the Dedoose qualitative software program was used as the volunteer coders were familiar with it, and it did not require the deep analysis functionality of the NVivo platform. Collectively, the tools mentioned earlier were used to achieve success in previous qualitative studies (Lamb et al., 2020; Lamb & Winter, 2021).

Sources of the Data

The study's primary data source was the transcripts from audio recordings of participant interviews. Secondary data sources included researcher-generated notes, journal entries, and memos collected and analyzed through the mechanisms of the MRL. The MRL also consists of notes and memos for developing and coding the research instrument. Finally, the MRL contains the researcher's reflexive notes and data entries on the data models, study processes, challenges, and mechanisms to reduce researcher bias.

Ethical Consideration

The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research released a report in the *Federal Register* in 1979 called “The Protection of Human Subjects, Belmont Report.” The report is the pivotal reference for three foundational principles for ethical human subject research: (a) respect, (b) beneficence, and (c) justice. Researchers are responsible for ensuring that participants are not harmed and are treated with respect and dignity while following strict directions for confidentiality and anonymity (Kim, 2021). The Embry-Riddle Aeronautical University (ERAU) Institutional Review Board (IRB) reviews and approves proposed studies involving human subjects, including the planned measurement instruments and procedures. It also provides a decision tree tool for researchers to determine if their proposed study requires IRB review and approval. If the research requires approval, it must be obtained before any data collection; the researcher must also have completed the *Human Subjects: Researcher* certification (ERAU Institutional Review Board, 2020).

Human subjects are the central focus of this study; the participants' perspectives are the study's central tenet and value proposition. The core of the study's design is personal interviews. The instrument is a specifically designed questionnaire with open-ended questions to support reflexive, rich, thick, contextual answers from the participants. According to ERAU IRB Decision Tree #1, this study requires an application to the IRB and the researcher to hold valid Human Subjects Researcher certification. A copy of the application and researcher's certificate is in Appendix A.

Following the ERAU IRB guidelines, personal interviews and focus group participation are voluntary and assessed as posing no greater risk to the participant than experienced in their normal daily activities. All participants must be at least 18 years old and, for this study, identified as having a stakeholder interest in UAM vertiports. Participants receive no compensation for volunteering in the study; however, they may gain intangible benefits from thoughtful reflection and discussing their perspectives with other UAM vertiport stakeholders in the focus group.

The time commitment is no longer than necessary; personal interviews took approximately 60 minutes each. The invitation to participate was extended via email to members of UAM stakeholder organizations through the network of collaborative working groups organized by the FAA, NASA, ASSURE, and ICAO groups. Participants willing to volunteer must sign and return the consent form, which outlines the terms and conditions of participating, including agreeing to the civil code of conduct for the focus group. A copy of the consent form and terms and conditions is located in Appendix A.

All participants' identifying information is kept confidential; any identifying information will be 'coded' as a number and date, and only information relevant to the study is collected. All participant discussions are recorded; however, these recordings were destroyed once transcribed into a coded Microsoft Word® document on the researcher's secure computer. After their participation, the researcher expressed gratitude and provided a debrief document containing contact information should the participant have additional questions or concerns. Finally, the researcher explained how their valuable contribution is essential to advancing knowledge in the field.

A certain level of researcher bias is expected and sometimes even required in qualitative research (Ravitch & Carl, 2016). Later, this chapter discusses techniques used to avoid researcher bias that would negatively impact the study findings (such as researcher conduct or bias in the instrument design).

Measurement Instrument

One semi-structured measurement instrument was used in this study; the questions for the individual participant interviews consisted of 18 open-ended research questions and 10 demographic questions. Initial instrument development leveraged the available literature, subject matter experts, the dissertation committee, an external qualitative research professor, and the primary researcher's considerable industry knowledge and experience. Before deployment, the instrument was refined and pilot-tested twice. The three subject matter experts (SMEs) were purposely selected from the study's population. Each of the SMEs was chosen from the stakeholder categories under investigation, and their selection was valuable in ensuring the following: (a) the quality, credibility, reliability, and transferability of the instrument, (b) curtailing researcher bias, and (c) contributing researcher reflexivity data to the master research log (MRL). The SMEs did not participate in the research study interviews; however, the transcript from the pilot study participant was highly contextual and, therefore, was included as one of the study transcripts. Any changes to the measurement instrument were reviewed and approved by the ERAU IRB. A copy of both instruments is located in Appendix A. Table 2.

Table 2

Measurement Instrument: Participant Individual Interview Questions

6 Central Questions [RQ], 14 Supporting Questions
1. Describe the current responsibilities of your role. **2. [RQ4]. How do your roles and responsibilities contribute to the safety efforts of the UAM ecosystem?** 3. What are the most significant safety issues/ responsibilities related to your role as a vertiport stakeholder? 4. What are the things stopping you from accomplishing these objectives?
5. [RQ2]. What are you currently experiencing at the forefront of the industry-wide problem-solving challenge? 6. What are the barriers to achieving your goals? 7. What is the most concerning factor when considering Vertiport's safe operation? What keeps you up at night? Why? 8. What resources do you currently use to guide your decision-making right now?
9. [RQ3]. How are you experiencing being at the forefront of the industry-wide problem-solving challenge? 10. What do you see as the actionable path forward? Why? 11. How does this perception influence your goals or plans to achieve safe outcomes? 12. What are the resource gaps that you need but don't have?
13. [RQ5]. How do you perceive other stakeholders at other companies or organizations are experiencing problem-solving? 14. Do you think other UAM Vertiport stakeholders share these safety concerns? Why? 15. How does your organization prioritize these safety concerns? Are they different from how other organizations prioritize their UAM Vertiport safety concerns?
16. [RQ6]. How likely are the interactions with other UAM stakeholder peers likely to influence your opinions on the design of safety processes, assumptions, and systems? 17. How active are you in industry working groups like the ones organized by NASA? Are these helpful to you? Why?
18. [RQ1]. What do you feel are unknown themes relating to stakeholders' perceptions, experiences, and opinions of operational safety at UAM vertiports? 19. What safety problems do you see that are not currently being addressed? 20. Is there anything else you would like to add for the researcher today?
Demographic Questions.
1. What is your age group: (20-30), (31-40), (41-50), (51-60), (61-70), (over 70). 2. What gender do you identify most with: (Male), (Female), (Non-binary), (Prefer not to answer). 3. What is your UAM vertiport stakeholder category: (R and D), (Fed Gov), (Aircraft and Component Manufacturer), (Airport and Local Municipalities). 4. Your title and role with this stakeholder are (title), (role). 5. How long have you been in this particular role: (less than one year), (1-2 years), (2-3 years), (3-4 years), (4-5 years), (5-6 years), (6-7 years), (7-8 years), (8-9 years), (9-10 years), (greater than ten years). 6. How long have you been with this particular stakeholder: (less than one year), (1-2 years), (2-3 years), (3-4 years), (4-5 years), (5-6 years), (6-7 years), (7-8 years), (8-9 years), (9-10 years), (greater than ten years). 7. What is your total annual salary: (less than 50K), (50-100K), (100-150K), (150-200K), (200-250K), (250-300K), (300-350K), (350-400K), (Greater than 400K).

8. Does your annual salary include the following: (none), (bonus), (company stock allocation), (performance incentives).
9. What is your current work arrangement: (onsite), (remote), (commute), (all of the above).
10. What is your highest education level: (high school), (higher education certification or diploma), (college or university degree), (master or advanced degree), (doctoral degree).

Data Analysis Approach

Aside from a central question, qualitative research projects, such as this one, can begin with no clearly defined theory or hypothesis; the researcher designs instruments with open-ended questions and, importantly, an open mind (Bazeley, 2013; Bazeley & Richards, 2000). There was no established or grounded theory for this study; therefore, the researcher did not engage in a priori coding or develop thematic analysis categories before the data analytics phase of the study. The coding task served to organize and analyze qualitative data, which was the first step in the data analysis. However, three separate coders were assigned to the thematic analysis to establish the codes and code hierarchy to minimize primary researcher bias and enhance the code and codebook reliability, confirmability, and transferability.

Coding and Code Reliability.

This initial data analysis was conducted in Dedoose. This open-source, cloud-based qualitative research platform enables comprehensive coding, collaborative coding, and data analysis independently or within a group of researchers. Suppose there was a grounded theory on which to base code hierarchy; if that were the case, code reliability is usually supported by code weight/rating decisions that present reliability results, which can include procedures such as Cohen's Kappa and Pearson's correlation coefficient. Once inter-rater reliability is established at no less than 80%, the data could be transferred into NVivo for more powerful analysis. However, as this research was investigating new emergent themes in an emergent industry with no established theories, the quality and reliability of the instrument were established by using the independent subject matter expert experience and advice, additional dissertation committee input, an external qualitative research professor, and three separate and qualified coders. The overlap and concurrence of the code and code hierarchy, agreement with codebook appropriateness, and overlap in the researcher's summaries provided confirmation of data adequacy and the effectiveness of the instrument in answering the research questions.

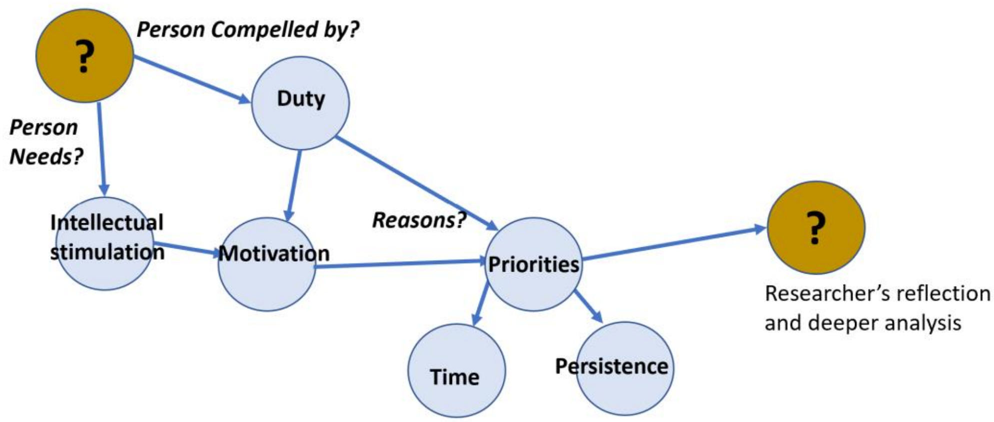
The coding task was achieved by building nodes, also called codes; each node represents an *in vivo* homogenous category of data (Bazeley & Richards, 2000). Nodes are named according to their central concept, often called parent node or parent code, and are often identified by keywords or phrases in each narrative file. However, although nodes may contain a central theme, there may be different contexts relating to the keywords or phrases within that node.

The Dedoose and the NVivo programs can code (or un-code) sub-categories within nodes. The primary nodes are parent nodes, and subcategories are *child nodes* (Bazeley & Richards, 2000; Lamb et al., 2020). The parent and child nodes will have different frequencies and prominence within the data, representing various interactions and relationships; both Dedoose and NVivo help visualize, measure, and analyze these data prominence by generating color-coded node strips, generating a *node hierarchy,* and *word clouds*. This initial data coding into the nodes, or stand-alone codes, was the precursor for deeper secondary analysis and exploration. An initial indication to the researcher that data saturation is being reached is when there is enough data within the code and subcodes to see overlapping and repeated expressions and themes, and no substantively different information is being generated. From these saturated data, the researcher is able to build and generate initial researcher data models. Models are often generated after dimensional axial coding, a qualitative research technique employed within the methodological approach developed by sociologists Glaser and Strauss (1978). Axial coding is a process that involves systematically organizing and connecting data to identify patterns and relationships (Saldaña, 2021). In the context of dimensional axial coding, researchers focus on understanding the dimensions or aspects of a phenomenon and how they interact. The process involves the identification of categories, properties, and relationships within the data. Categories represent concepts or themes that emerge from the data, and properties describe the characteristics or attributes of these categories. Dimensional coding then helps researchers explore the variations and connections between these categories and properties. This qualitative method is time consuming and typically involves constant comparison, where researchers continually compare data to refine and develop emerging categories and their relationships. Dimensional axial coding helps researchers build a comprehensive and nuanced understanding of the phenomenon under investigation, allowing for the development of data models and possible emergent themes from the complexity and richness of the data.

Figure 16 illustrates an example of a researcher-generated initial data model from the iterative primary analysis of the coding. This study's model generation copies are located in the *data models* tab in the MRL.

Figure 16

An Example of a Researcher-Generated Data Model



Note. This generic model developed by the researcher does not reflect the data in this study. Developed from guidance in the NVivo Project Handbook by P. Bazeley and L. Richards, 2000, SAGE. Copyright 2000 by SAGE.

***Qualitative Data Analysis*.**

Having established data adequacy [data saturation] and coding reliability, the researcher thanked the volunteer coders for their time and expertise and transferred the codebook into NVivo for the detailed analysis described in chapter four. The NVivo qualitative data analytics platform is capable of sophisticated and powerful analytics for professional qualitative research. Unlike some introductory platforms, the NVivo program is not open source, and users are charged on a 12-month subscription basis due to the powerful and unique data analysis functions. The analytic functions used in this study include *Matrix Code Analysis, Code and Child Code Visual tools, Boolean Matrix Intersection, Matrix Cooccurrence, Cross-Case Analysis, Data Relationship Mapping, Frequency and Sentiment Measurement,* and more. From these deeper secondary analytical processes, the researcher was able to generate data models, which can be compared with the NVivo developed conceptual *model cluster concepts,* such as dendrograms, which help researchers recognize patterns in the data emerge to represent themes (Bazeley & Richards, 2000; Fofana et al., 2020). These analyses in the NVivo program helped to triangulate the within-case data, indicating both the particularity and the commonality within the participant transcripts.

As presented earlier in this chapter, data analysis in this qualitative study was concentrically iterative as it progressed through the four design sequences, culminating in the detailed data analytics processes in phase four. Each phase contributed and ensured that the study's findings were supported by *rigor, quality*, and *credibility* at the end of each phase. The notes, memos, and journal entries associated with each of the four phases were captured in detail within this dissertation and through notes within the master research log for an auditable and repeatable study.

Participant Demographics

Collecting detailed data on participant demographics was critical in understanding the characteristics of the selected UAM vertiport stakeholders and their populations. Therefore, this study asked ten demographic questions presented earlier in Table 2. In addition to asking usual questions about age, gender, and education, other questions investigate *industry-focused* characteristics relevant to their role.

The industry-focused demographic questions include the type of UAM vertiport category they belong to, how long they have been in that role and at that organization, and what kind of remuneration package they receive. These elements were considered to be essential data to collect because the sample frame of participants is spending their daily working lives focused on primary challenges and engineering solutions for safe operations at UAM vertiports. Moreover, this demographic and descriptive information was significant at the time, as the emerging and novel UAM industry is still largely conceptual. In addition, the individual roles of UAM vertiport stakeholders are also emergent, and some role descriptions may align with traditional functions; however, the literature points to many non-traditional roles and functions that are yet to be explored. Therefore, the rationale for the demographics questions was to help support understanding the characteristics of UAM professional roles.

Qualitative Data Analysis Process

The data analysis process in qualitative studies is dynamic, complex, and highly contextualized; the researcher must be systematically dedicated to achieving rigor throughout every process and procedure in the study. Furthermore, these data analysis processes are often strategically sequenced to enhance *rigor* (Creswell & Miller, 2000; Lincoln & Guba, 1985; Ravitch & Carl, 2016). Rigor refers to the study's overall quality and validity and encompasses many concepts, methods, researcher actions, and considerations (Barbour, 2001; Creswell & Creswell, 2018; Creswell & Miller, 2000). Therefore, within the paradigm of qualitative research, there are three main concepts: (a) validity, (b) reliability, and (c) transferability. Within these three primary concepts are core values, including *credibility, dependability,* and *transferability* (Creswell & Creswell, 2018; Creswell & Miller, 2000). Additionally, strategies and processes to enhance validity, reliability, and transferability are often applied in systematic strategic cycles or phases (Higginbottom & Liamputtong, 2015; Jagosh et al., 201,2022; Ravitch & Carl, 2016).

This study employed four strategic phases, which were assessed as essential when investigating a complex latent phenomenon, such as a group's lived experiences and perceptions, reflections, and opinions (Creswell & Creswell, 2018; Higginbottom & Liamputtong, 2015; Jagosh et al., 2021; Ravitch & Carl, 2016). The data collected from participant interviews must be highly contextualized, capturing the fidelity of the participant's lived experiences and perceptions. The additional data analysis processes used within phase four are discussed further in Chapter IV chapter four. They consist of three stages used by the primary researcher to build a level of rigor and reliability that supports the complex nature of phenomenological research.

Highly contextual data enables deep exploration and the identification of codes and sub-codes (Bazeley, 2013; Bazeley & Richards, 2000). However, a thematic analysis is not completed in one cycle; the researchers (coders) must re-analyze the data in each case several times, exploring deeper meanings within the context of each case and all the cases collectively (Bazeley, 2013: Bazeley & Richards, 2000). The primary researcher used validity tools such as Tesch’s eight-step coding process, which is a tool to uncover deeper meaning in contextual data and reduce researcher bias while increasing the credibility and integrity of the data analysis (Creswell & Creswell, 2018; Tesch, 2013). The primary researcher shared directions, guidelines, and a copy of Tesch’s coding process with the volunteer coders to enhance *credibility* and *integrity* and minimize the volunteer coding bias.

Additionally, during instrument design and thematic analysis, the researcher captured reflexive data (memos, notes, and journal entries) into the MRL, adjusting the conceptual data models as dialogic exchanges with SMEs and peer coders to explore the rationale for codes and subcodes. This strategy enabled a more profound understanding of the sample frame, which is more likely to be transferable to the broader homogenous group (Barbour, 2001). Hammersley and Atkinson (1983) reinforced this view, and they posit that quality and validity assumptions are made not from the data but the inferences drawn from them (Creswell & Miller, 2000; Downey, 2012). Therefore, the volunteer coders submitted a detailed summary of the rationale behind the established code hierarchy, highlighting commonality in their inferences drawn from the data, and thus, further supporting the primary researcher's fidelity for the final comprehensive data analysis in phase four (Creswell & Miller, 2000; Downey, 2012; Ravitch & Carl, 2016).

Validity Procedures. Validity in qualitative research is often described in terms of values, such as *trustworthiness*, *integrity*, *authenticity*, and *credibility*. These *values* are engineered into this study's design and govern the researcher's conduct. The strategic sequencing of the method includes strategies and procedures to check the codes and sub-codes accuracy and the context of emerging inferences from the data (Higginbottom & Liamputtong, 2015; Jagosh et al., 2021; Ravitch & Carl, 2016). An accepted technique is to view the data through different *perspectives* or *lenses* while analyzing overlapping and common themes (Creswell & Miller, 2000; Guba & Lincoln & Guba, 1985, 1994; Ravitch & Carl, 2016). Examining the data through different lenses is also a comparative analysis achieved by *triangulating* the data from multiple data *sources* and using different lenses (Creswell & Miller, 2000). Triangulation of data sources can include within-participant data [cross-case] and external data such as SME, researcher, and peer coder (Creswell & Creswell, 2018; Creswell & Miller, 2000; Tesch, 2013). This study used four triangulation procedures, including (a) *perspectival triangulation*, using data from multiple perspectives of recruited participants; (b) *method triangulation*, using methods from at least two or more qualitative paradigms (strategies); (c) *data triangulation* using iterative triangulation; and finally (d) *investigator triangulation*, using all data collected and analyzed through the different sources (the volunteer SME's, dissertation committee, external qualitative research professor, and the three independent qualitative coders) and collected and reflected upon through the dissertation paper, and the researcher's personal MRL. These validity procedures are all included under the label of triangulation (Creswell & Miller, 2000).

In addition to triangulation, Creswell and Miller (2000) presented a table of nine validity procedures executed through various perspectives or lenses using the three qualitative *paradigms* established by Guba and Lincoln (1994). The three qualitative paradigms represent a different archetype or strategy of inquiry, and they include (a) the *postpositivist* or *systematic* paradigm, where the researcher uses systematic methods of inquiry and rigorous methods; (b) the *constructivist* paradigm, where the researcher uses contextualized, pluralistic, interpretive, open-ended perspectives; and (c) the *critical* paradigm, where the researcher aims to uncover hidden, emergent themes based on narrative accounts. As discussed in Chapter II, this study draws from the plurality of both the narrative and phenomenological perspectives; therefore, it uses elements from all three paradigms in different study phases. Table 3 presents a correlation matrix mapping the strategies [paradigms] and perspectives used for validity procedures in this study.

Minimizing Researcher Bias. This four-phase study design supports reflexive and dialogic engagement throughout each iterative phase of the study. Reflexivity and dialogic engagement refer to the researcher's critical self-inquiry, asking questions to challenge a perception formed from the thematic analysis, such as, *Is my experience influencing this interpretation?*, or *Could this be interpreted differently by another participant or SME?* Reflexivity is incorporated continuously through the study's process procedures and includes dialogic data from the SMEs, the independent qualitative professor, the researcher's committee, and the volunteer coders. Reflexivity and dialogic data were captured and analyzed in several ways; the master research log (MRL), the NVivo program, and the details within this chapter and Chapter IV Chapter four, thereby increasing the transparency of the data and the analysis process (Alvesson & Sköldberg, 2017; Creswell & Creswell, 2018; Tesch, 2013). The reflective questions for each element of validity and those associated with Tesch's coding strategy are included in the MRL, and a copy is located in Appendix B.

Table 3

Correlation Matrix of Paradigms and Perspectives of Validity Procedures

Paradigm Assumption	**Postpositivist Paradigm**	**Constructivist Paradigm**	**Critical Paradigm**
	Researcher uses systematic methods of inquiry and rigorous methods	*Researcher uses contextualized, pluralistic, interpretive, open-ended perspectives*	*Researcher aims to uncover hidden, emergent themes based on narrative accounts*
Lens of the Researcher	Four-phase design for continual in-phase triangulation. SME feedback, collaboration on instrument design, and triangulation for Tesch's coding strategy. Three separate coders Researcher reflexivity and documented data building the MRL.	Research perspective for narrative and phenomenological lenses of inquiry. Tesch's coding strategy. Researcher reflexivity documented in MRL (journal, memos, notes). Researcher concept model generation. Dialogic engagement with SMEs and coders.	Researcher qualifications and experience in related industry and industry forums. Tesch's coding strategy. Researcher reflexivity, analysis of MRL. Four separate data sources (SME, Participant, Coders, and Researcher).
Lens of the Participants	Thirteen detailed relevant questions about phenomena. Asked for *rich thick* descriptions of their experience. Participant de-briefing	Open-ended specific and non-specific questions. Asked for rich thick descriptions of their experience to draw contextualized answers.	Open-ended questions. Reflective questions. Secondary questions. Asked for rich thick descriptions of their experience.
Lens of the SME and Peer Coders	Documented iterative dialog with researcher. Iterative instrument development. Triangulation from initial instrument feedback. Assessment of final outcomes.	Documented iterative dialog with researcher. Iterative instrument development. Triangulation from initial instrument feedback. Prolonged dialogic engagement with SMEs. Assessment of final outcomes.	Documented iterative dialog with researcher. Iterative instrument development. Triangulation from initial instrument feedback. Assessment of final outcomes new knowledge.
Lens of the Reader	Critical audit of the processes.	Critical audit of the processes and thick rich description (contextuality) of the inferences.	Critical audit of the process's judgment and debriefing of new knowledge.

Reliability Procedures. Reliability in qualitative research refers to the *stability* and *consistency* of all procedures and strategies used in the study, such as coding the data (Alvesson & Sköldberg, 2017; Bazeley, 2013; Bazeley & Richards, 2000). In addition, reliability includes values referred to as *dependability confirmability* (Ravitch & Carl, 2016).

Inter-Rater Reliability**.** Researchers understand the concept of reliability regarding the percentage of agreement between researchers, usually relating to coding; for example, in the presence of an established theory, 80% agreement between two or more researchers on codes indicates good reliability (Creswell & Creswell, 2018; Yin, 2009). However, as this project represented a significant gap in the literature and is novel in its approach, there was no established theory or code hierarchy on which to perform traditional inter-rater procedure; therefore, the coders generated code hierarchy and inferences indicated a high level of overlap and commonality drawn from the data (Creswell & Miller, 2000; Downey, 2012; Hammersley & Atkinson, 1983). Further studies may use the established codebook from this research to develop theory and then assess inter-rater metrics, which may provide a further understanding of correlating or divergent views.

Once the participant interviews were transcribed into Word documents, they were saved as PDF documents and sent to the coders, who uploaded them into the Dedoose QDAP. After the initial introduction meeting, the coders begin the initial thematic analysis. There were three specialized coding meetings after the initial introductory session. After each meeting, the code rationale was discussed, and codes and parent codes were refined and grouped into logical categories that became the parent codes. Each meeting revealed a high level of agreement between the coders on both the child code rationale and the parent code categories. This was likely due to the highly refined and appropriate instrument design.

After each code meeting, the coders returned to the transcripts to perform a deeper thematic analysis focusing on both the narrative and the phenomenological perspectives to discover and refine the code of the sub-codes. The final thematic analysis concluded with each coder submitting a report via email with their Dedoose output report. The primary researcher was not involved in the coding; however, the primary researcher hosted the coding meetings and provided any technical information or additional information the coders needed to complete their final coding. The primary researcher confirmed commonality and overlapping concepts and themes connected to the coding; this was confirmed within each of the three coders' summary reports; thus, the coding task was considered complete. The established code book was transferred into NVivo for the comprehensive three-stage data analysis process outlined in Chapter IV.

Data and Study Process Reliability**.** Procedures to support total study reliability include recommended best practice strategies through rigorous documentation and record-keeping for all *internal* and *external* data sources (Bazeley, 2013; Bazeley & Richards, 2000; Creswell & Creswell, 2018; Ravitch & Carl, 2016). Comprehensive and accurate record-keeping was the function of the details in Chapter IV; these appendices notes are both within NVivo and the master research log (MRL), all of which serve as a project record (Bazeley, 2013; Bazeley & Richards, 2000). The data collected and analyzed within NVivo, the master research log, and this dissertation represents (a) SME dialogic engagement data for instrument *confirmability* and *transferability*, (b) coder reflexive rationale and coding reliability, and (c) researcher reflexivity data. During iterative instrument design and phase four data analysis, the MRL was used iteratively, forming an *internal* data source, which became a mechanism to check all data records, support triangulation, enhance data interpretation, and increase reliability (Alvesson & Sköldberg, 2017).

Transferability. In qualitative research, transferability is "the way in which qualitative studies can be applicable or transferable to broader contexts while still maintaining their context-specific richness" (Ravitch & Carl, 2016, p.168). Transferability in the context of this study means that the data and results from the data would be similar or consistent with the broader community of other UAM vertiport stakeholders that did not participate in the study. The hallmark of high-quality qualitative research is *transferability* and *particularity* (Creswell & Creswell, 2018; Green & Caracelli, 1997). *Particularity* refers to the specific contextual richness, for example, the uniqueness of each stakeholder's perspectives and experiences. Transferability is often juxtaposed with generalizability and external validity (Lincoln & Guba, 1985; Leung, 2015; Lincoln & Guba, 1985). Traditionally, the generalizability of qualitative research was not expected (Leung, 2015). However, with advancements in data synthesis capabilities, especially from metadata analyzed from multiple sources and perspectives, generalizability becomes a consideration (Finfgeld-Connett, 2010; Leung, 2015).

Initially, qualitative researchers using case study designs introduced the term *qualitative generalizability* (Yin, 2009); the rationale was that case studies often use structured processes and apply *replication logic*. This view was countered by Green and Caracelli (1997), who posit that the value of qualitative research is derived from particularity, which may be difficult to replicate. Therefore, assessing qualitative generalizability may require acknowledging that generalizability exists on a continuum, dependent upon the design and approach (Creswell & Creswell, 2018; Green & Caracelli, 1997; Gibbs. 2007; Ravitch & Carl, 2016). An interesting observation of the emergent advanced air mobility industry is that although stakeholders have very different backgrounds and disciplines, the applied focus of their problem-solving activities as it applies to UAM Vertiports, and the small size of this specialized industry makes for a high level of generalizability within the population of interest.

This study design and approach used multiple comprehensive strategies to increase validity, reliability, and transferability. Thus, this robustness enhances external validity and qualitative generalizability to the small and specialized homogenous group. Transferability procedures were recorded in the MRL and related to dialogic engagement with the highly knowledgeable and experienced industry SMEs, the independent qualitative professor, and the volunteer expert coders. A key focus for the transferability of the data is the development of the instruments and their robust appropriateness, as indicated by the pilot tests. During the instrument design, pilot tests, and refinement, the researcher asked reflective questions, including, *Am I asking details about their stakeholder role? Will the participants have the relevant background and experience to answer my questions?* These reflections manifested in the instrument mapping exercise, which was also used to check and enhance validity, reliability, and transferability, and are located in the MRL on the Reflective Questions sheet. A copy has been reproduced in Appendix B.

Summary

This chapter comprehensively explained the chosen methodology to explore themes relating to stakeholder perspectives of operational safety at UAM vertiports. These stakeholders deal with a complex phenomenon, an industry-wide problem-solving effort to solve problems to a theoretical concept yet to emerge as a daily reality. Therefore, this complex problem required exploration and examination through multiple perspectives (narrative and phenomenological) while drawing strategies from three qualitative paradigms (postpositivist, constructivist, and critical). The research questions dictated the necessity for strategic sequencing of this four-phase design.

Importantly, this chapter provided an overview of the homogenous community of interest, a sample frame of various stakeholder categories that emerged from the literature. These specific individuals, purposefully selected, work for stakeholders in the emerging advanced aviation industry focusing on safe operations of vertiports. Ethical considerations for treating human participants, including a code of conduct, are essential for this study, which followed the guidelines outlined by the Embry-Riddle Aeronautical University Institutional Review Board. Moreover, this project leveraged the dialogic engagement and expertise of industry subject matter experts, an external qualitative professor, and independent coders who provided critical feedback, enhancing researcher reflexivity throughout the entire study, along with the consistent support and guidance of the knowledgeable dissertation committee and industry chair.

Further, this chapter explained the details and characteristics of the four design phases. Two notable features of this study are the design and pilot testing of the instrument and the engagement of three independent coders, which allowed the capture of extra data in the master research log (MRL). The chapter explained the importance of measuring data saturation and coding reliability. In addition, this chapter described how the instrument for the personal interviews was collaboratively developed, refined, and implemented and how that data was captured and transcribed into the qualitative data analysis program Dedoose for code generation and thematic analysis. Additionally, this chapter introduced the fourth phase of the study, whereby the primary researcher imported the codebook and used NVivo® for the three-stage comprehensive deep analysis contained in the next chapter. The comprehensive data analysis used four types of triangulation methods, and the end of this chapter demonstrated how these perspectives and strategies were used to enhance validity, reliability, and transferability while explaining the qualitative values of each concept, such as *quality*, *trustworthiness*, *integrity*, *authenticity*, and *credibility*.

Finally, the researcher is responsible for faithful dedication to qualitative concepts, processes, and mechanisms to support high-quality, repeatable results; they are the primary instruments in qualitative research. This role is especially critical when the researcher uses collaborative methods such as independent SMEs and multiple coders. The next chapter discusses the results and findings from the thematic analysis, explores emergent themes, and draws inferences to understand the perspectives of UAM vertiports stakeholders.

Chapter IV: Results

This chapter reports the findings based on the qualitative methodology and follows the research design discussed in Chapter III. The data was gathered in the summer of 2023, and results are presented around finding the answers to the primary and secondary research questions through an increasingly comprehensive three-phase process analysis. The first phase of the analysis process was a high-level primary thematic analysis of the codes, subcodes, frequency, and data patterns as described in the previous chapter; following this is a secondary analysis using *affect* and *sentiment* as phenomenological tools, the purpose of using affect and sentiment is to support insights into the phenomenological perspective of the research. The last phase is the tertiary analysis, a highly detailed examination of the significant primary and secondary analysis results. A detailed process map included at the start of the chapter and referenced at each analysis phase summary will help the reader follow the analysis process.

The main participant data included the pilot study results, as the narrative in the transcripts was *rich and thick* (Creswell & Creswell, 2018; Bazeley, 2013) and contained consistent and valuable content that aligned with the other 19 participant transcripts. The chapter will begin with the demographics and descriptive statistics and outline the procedures the three independent coders followed to enhance qualitative reliability and validity and minimize primary researcher bias. Finally, this chapter will conclude with a brief explanation and summary of the data analysis findings and the answers to the research questions.

Generalized Demographics.

A total of 20 participants volunteered for this study, and five were women. Given the specialized scope, scale, and novel characteristics of the Advanced Air Mobility industry at the time of this study, participant identity was reported in generalized rather than specific participant demographics. The participants' ages were recorded according to an age range. The youngest participant, a woman, reported her age to be between 21 and 30 years, the oldest participant was a man over 80, and the largest age range group was 51 to 60, all men. The total demographic results are produced in Table 4, with salary medians in the Histogram in Figure 17.

Descriptive Statistics

All participants were actively working in the Advanced Air Mobility industry; five were from the Federal Government in various roles, including *Program Lead, Aviation Safety, Chief Technologist for Future Aviation, Aviation Safety Inspector,* and *Accident Investigator and Training Manager*. Five participants worked for Aircraft and Aircraft Component Manufacturers; their reported roles included *Airspace Policy and Government Affairs Lead, Research Director, CEO,* and *Industry Leader*. Five participants were from Research and Development, which had roles of *CEO, Chief Technical Officer*, and *Executive Director of Advanced Aviation Technology*. Finally, there were five participants from the Airport and Municipality stakeholder group; this group included the roles of *Director of Infrastructure*, *Head of Vertiport Operations*, *Executive Aviation Planner*, and *Partnership Acquisition Manager*. Some participants requested a descriptor for their role title to preserve participant anonymity rather than their official role title.

Other descriptive information includes the assigned Case ID, coded to the date of the participant interview, and an alphabetical letter for differentiation and to identify the sequence the participant was interviewed in (A was the first participant); tables and figures in this chapter may contain either the complete Case ID or just the alphabetical identifier; for example, 1202023C may be referred to as Participant C, who was interviewed on January 20, 2023. The table contains selected participant demographics and descriptive data; the full descriptive table is in the Master Research Log under the Case Demographics tab.

Table 4

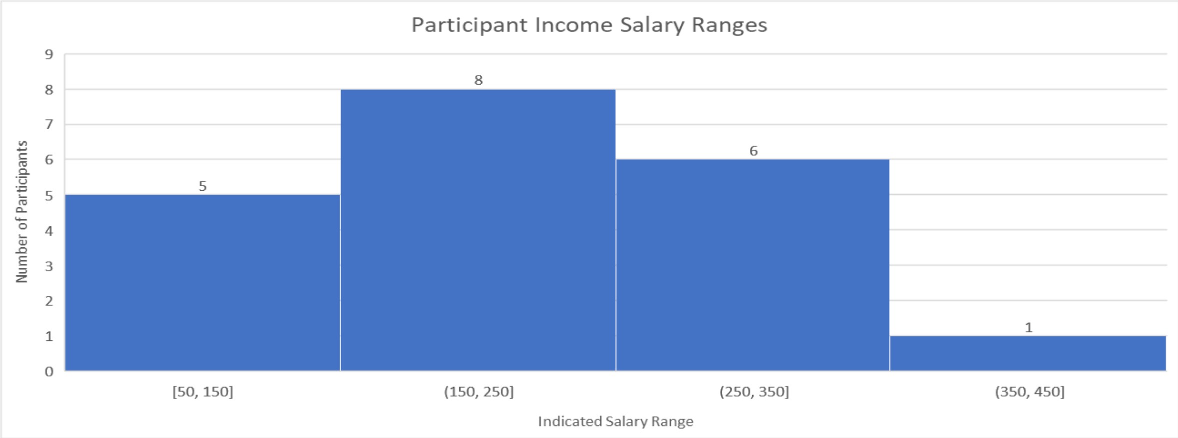
Participant Demographics and Descriptive Data

Case ID	Age	Gen	Category	Role Tile	Time In Role	Salary	Incentives	Education
1202023A	41-50	F	Aircraft and Component Manufacturer	Airspace Integration Safety Policy Lead	1-2 years	100-150	None	Master's Or Advanced Degree
1202023C	31-40	M	Aircraft and Component Manufacturer	Aviation Policy and Gov Affairs Lead	2-3 years	200-250	Company Stock Allocation	College Or University Degree
1232023E	31-40	F	Aircraft and Component Manufacturer	Policy - regulations	3-4 years	250-300	Performance Incentives.	Master's Or Advanced Degree
2232023O	over 80.	M	Aircraft and Component Manufacturer	Research Director	greater than ten years.	350-400	Bonus	College Or University Degree
3172023T	61-70	M	Aircraft and Component Manufacturer	CEO industry leader	9-10 years	250-300	None	Master's Or Advanced Degree
1312023H	31-40	M	Airport and Local Municipalities.	Partnership acquisition Manager	1-2 years	200-250	Bonus	Master's Or Advanced Degree
222023I	31-40	F	Airport and Local Municipalities.	Director of Infrastructure	2-3 years	150-200	Company Stock Allocation	Master's Or Advanced Degree
272023k	31-40	M	Airport and Local Municipalities.	Director of Infrastructure	1-2 years	250-300	Performance Incentives.	Master's Or Advanced Degree
2102023L	20-30	F	Airport and Local Municipalities.	executive and aviation planner	3-4 years	200-250	Performance Incentives.	Master's Or Advanced Degree
3202023S	31-40	M	Airport and Local Municipalities.	Vertiport Operations	1-2 years	250-300	Company Stock Allocation	Master's Or Advanced Degree
1202023B	51-60	M	Fed Gov	Program Lead	1-2 years	100-150	None	Master's Or Advanced Degree
232023J	41-50	F	Fed Gov	Aviation Safety	1-2 years	100-150	Performance Incentives.	College Or University Degree
2102023M	51-60	M	Fed Gov	Chief Technologist for Future Aviation	2-3 years	150-200	None	Master's Or Advanced Degree
312023Q	over 70.	M	Fed Gov	Aviation Safety Inspector	greater than ten years.	250-300	None	College Or University Degree
1162023R	51-60	M	Fed Gov	Accident Investigator Training Manager	greater than ten years.	less than 50	None	Master's Or Advanced Degree
1202023D	51-60	M	R and D	Executive Director Advanced Tech Initiatives	3-4 years	200-250	None	Master's Or Advanced Degree
1242023F	51-60	M	R and D	CEO industry leader	5-6 years	150-200	None	College Or University Degree
1262023G	51-60	M	R and D	Chief Tech Officer	4-5 years	100-150	None	Higher Education Certification Or Diploma
2202023N	51-60	M	R and D	President and Executive director	5-6 years	150-200	Performance Incentives.	Master's Or Advanced Degree
12222023P	51-60	M	R and D	President and Executive director	6-7 years	250-300	Performance Incentives.	Master's Or Advanced Degree

Participant salary varied across each of the stakeholder groups; the lowest paid participant worked for the Federal Government and reported their salary at under $50 thousand per annum, while the highest salary reported was for a participant working for an Aircraft Component Manufacturer between $350 – $400 thousand per annum. Four participants from various stakeholders reported their salary to be between $100 – $150 thousand per annum, four more between $150 –$200 thousand, and another four reported their salary at $200 – $250 thousand, while six participants reported their salary between $250 – $300 thousand. Figure 17 presents a Histogram of participant salary ranges as reported by participants.

Figure 17

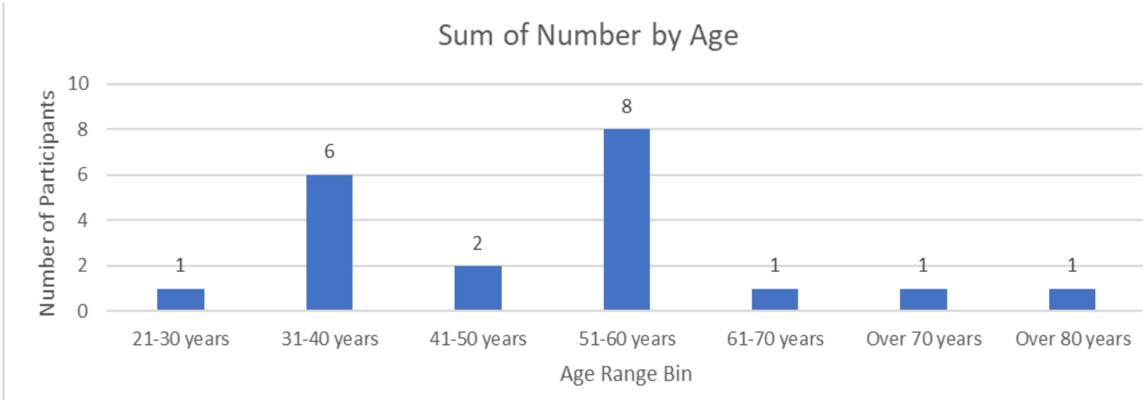
Histogram: Participant Salary Ranges



The advanced aviation industry is still in the emergent stage; therefore, it was not surprising that most (*n* = 16) of the participants were in their roles for less than six years, with only four participants reporting they had been in the role for more than nine years. Each of these longer-serving participants identified as men and reported their age to be over 50, and all held senior management positions in the Federal Government and Aircraft and Component Manufacturer stakeholder groups. Interviews with these four men indicated that they all came from a traditional aviation research and development background before their current stakeholder group, and one described himself as one of the pioneers or “Grandfathers of UAM.” Figure 18 presents the participant-reported age ranges.

Figure 18

Reported Participant Age



All five participants from the Airport and Local Municipalities group reported they had less than four years in their roles, with three having less than two years. Analysis of stakeholder groups in isolation revealed interesting results: participants in the Airport and Local Municipalities stakeholder group (a) were the youngest, (b) reported the least amount of time in their roles, (c) had the highest reported salaries, (e) each possessed a master's degree, and (f) included two of the five female participants.

In contrast, the Research and Development Stakeholder group consisted of all men reporting their age within the 51-60 age range. The Federal Government and Aircraft Component manufacturing stakeholders were similar in the diversity in their participants' reported time in the role and gender, including one and two females, respectively. The noticeable difference between these two stakeholder groups was the reported annual salary, estimated at $150 and $225 thousand annually.

Qualitative Reliability and Validity Procedure Results

No *a priori* coding or code categories were developed until the researcher and the three independent coders completed a review of all the transcripts. This procedure enabled each of the four researchers to form their perceptions of the transcripts independently, and the three independent coders were instructed to import the transcripts into their Dedoose qualitative research platforms and make independent notes on possible codes and subcodes. As described in the procedure from Chapter III, the coders were provided a copy of Techs' coding strategy and instructed on qualitative research methods. All three independent coders each hold a Ph.D. and completed prior coursework on qualitative research methods.

The first of three coding meetings occurred in March 2023, when the coders discussed their initial perceptions and proposed a list of possible codes and sub-codes. A total of three coding meetings were hosted and observed by the lead researcher. At this point of the investigation, the lead researcher's function was to answer technical or advanced aviation questions. From this iterative process, a project codebook, including the parent and child codes, was unanimously agreed upon and developed (a copy of the codebook is contained in Appendix F). The three independent coders summarized their findings from the 20 participant transcripts from the established codebook. The primary researcher remained distant from the procedures, only offering technical background and procedural advice to minimize bias.

Each researcher independently submitted their Dedoose coding reports along with a summary of their findings. The coder's summaries indicated considerable overlap and commonality; in addition, the coder's summary reports established the following: (a) data saturation was achieved, (b) each of the transcripts exhibited rich contextual content, (c) the established codes and codebook was highly appropriate and fit for purpose, and (d) the research questions could be sufficiently answered from the established Parent and

Child Codes. A copy of the independent coders' reports is in the Master Research Log under the Independent Coder Results tab.

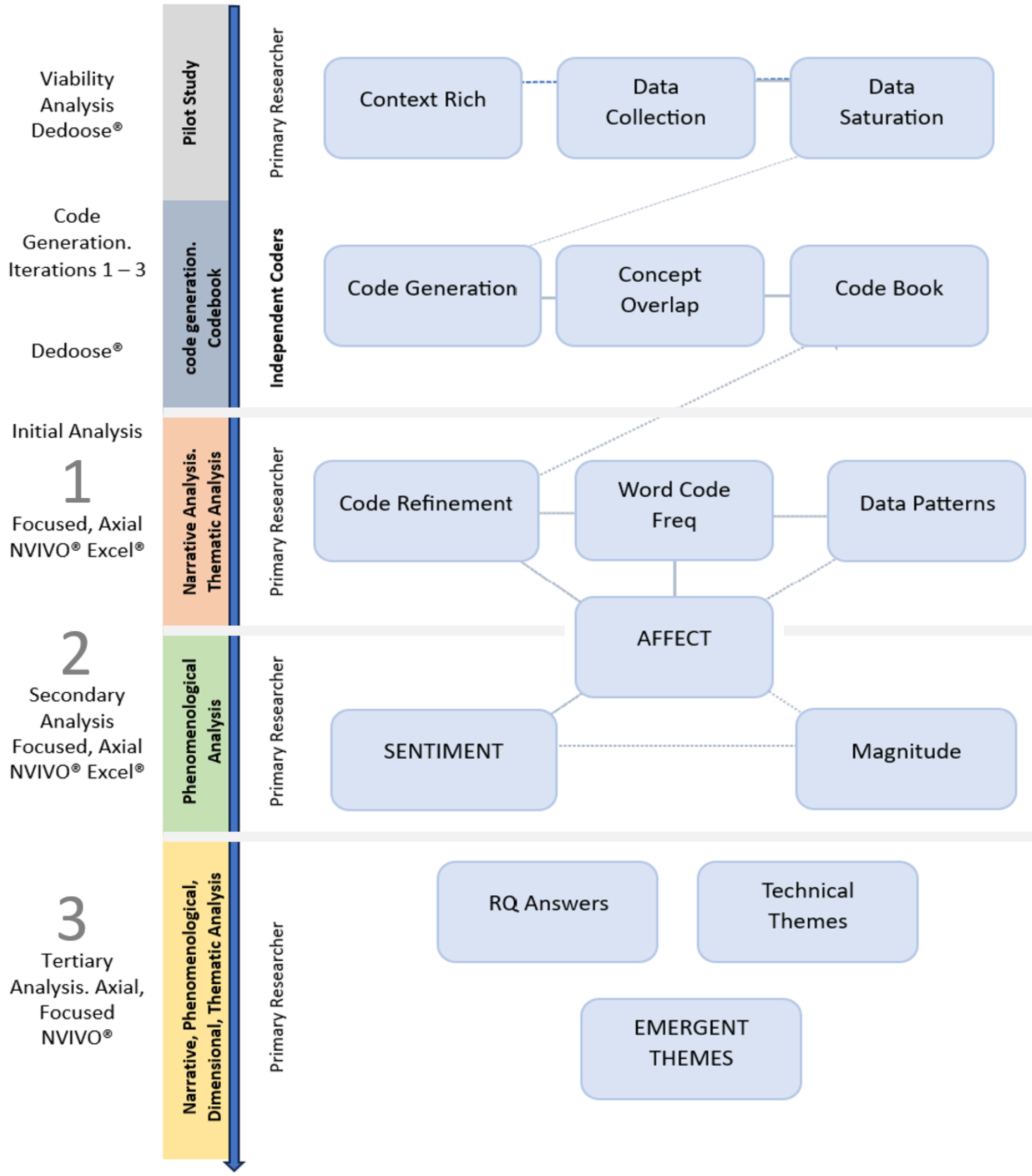
Data Analysis Process Map

Data analysis followed a methodical process for structuring and theorizing qualitative data (Bazeley, 2013). After the viability (pilot study) and code generation iterations with the independent coders, the primary researcher imported the established codebook into NVivo® and performed the first phase analysis. The first phase was a continuation of the Narrative and Thematic Analysis of the 20 transcripts. During this process, several codes needed further descriptive clarification; however, the codes and sub-codes were found to be highly suitable and appropriate to the data, further supporting the reliability and validity of the codebook; code and sub-code, word frequency results, and data patterns also emerged from this initial phase.

The secondary analysis used the results of the initial analysis of the most frequent codes using focused and axial coding of *Affect* and *Sentiment* to progressively join the narrative and build phenomenological concepts and dimensionality within the *Secondary Analysis* (Saldaña, 2021; Schatzman, 1991). Finally, through the *Tertiary Analysis* phase, progressively granular analysis enabled the emergence of plausible answers to the research questions and possible new theories. The initial analysis of the results in the first part of this chapter establishes the foundation and basis to answer the central research question (RQ1). In contrast, the secondary and tertiary analysis further explores the most prominent findings to develop a foundation of understanding to answer the supporting research questions (RQ2, RQ3, RQ4, RQ5, and RQ6). Additionally, analysis of some of the instrument questions provides specific insights that are examined. The analysis process has been simplified in Figure 19, Analysis Process Flow Chart.

Figure 19

Analysis Process Flow Chart



Note. The figure created by the author is based on the narrative from Salenda, 2021, and Bazeley, 2013.

The central research question was overarching, a complex question aimed at understanding the higher level of more general themes; therefore, the first phase of primary data analysis investigated the most frequent Parent Codes:

Central Research Question **RQ1.** What are the emergent or unknown themes relating to stakeholders' perceptions, experiences, and opinions of operational safety at UAM vertiports?

To gain structure around **RQ1**, five possible supporting research questions were asked and directly incorporated into the 20 questions in the research instrument. A copy of the instrument is located in Appendix C. As characteristic of qualitative research, an Iterative analysis was needed to answer each of the supporting RQs, which are presented here:

RQ2. What are the UAM vertiport stakeholders experiencing at the forefront of the industry-wide problem-solving challenge?

RQ3. How are the UAM vertiport stakeholders experiencing being at the forefront of the industry-wide problem-solving challenge?

RQ4. How do UAM stakeholders' roles and responsibilities contribute to the safety efforts of the UAM ecosystem?

RQ5. How do these UAM stakeholders perceive their peers (stakeholders at other companies or organizations) experiencing problem-solving?

RQ6. How likely are interactions with other UAM stakeholder peers likely to influence the participant's opinions on the design of safety processes, assumptions, and systems?

Data Analysis

Establishment of Codes and Subcodes

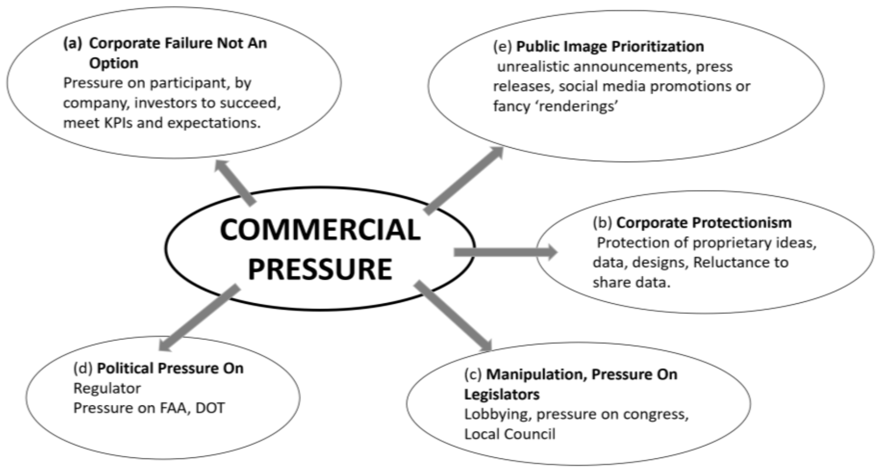
To answer **RQ1**, the initial analysis needed to organize and categorize the data from the iterative transcript review; possible codes emerged from the initial review. The codes were analyzed and organized into categories or related data groups. Seven main categories emerged from this initial analysis by the independent coders. These seven categories formed the parent codes and included (a) *Affect*, (b) *Commercial Pressure,* (c) *Gaps and Lacks*, (d) *Highest Priorities*, (e) *Identified Vertiport Problems,* (f) *Safety Culture,* and (g) *Stakeholders, Personal Perceptions.*

At this stage of the analysis, it is essential to acknowledge that these seven categories are *not* yet identified as the emergent themes of this study; they are the foundation and rationale for the seven parent codes that emerged in the first iterations of the coding review and coding meetings. The *parent codes* are a way to organize the data and expose more specific context that supports the discovery of nested *child codes*; for example, *Commercial Pressure* was a re-occurring expressed perspective within participants' data. Therefore, *Commercial Pressure* became a parent code, while more specific descriptors were assigned to describe or manifest Commercial Pressure within the participants' particular sentiments and expressions of *Affect*.

More specific expressions of *Commercial Pressure* became nested Child codes and included (a) *Corporate Failure Not An Option,* (b) *Corporate Protectionism*, (c) *Manipulation, Pressure On Legislators*, (d) *Political Pressure On Regulators,* and (e) *Public Image Prioritization*. The data model in Figure 18, adapted from Bazeley (2013), shows the coder's model of how *Commercial Pressure* manifested in the participant data.

Figure 20

Commercial Pressure Data Model



Note. The author developed a figure of manifestations of Commercial Pressure based on a narrative from Bazeley, 2013.

A total of 47 Child Codes were identified throughout the data. The independent coders agreed unanimously that the logical distribution and saturation of Child Codes through all participant transcripts indicated rich and highly contextual data, with considerable consensus and overlap with their results. Table 5 presents the seven Parent Codes and their nested 47 Child Codes. The complete codebook with code descriptions and examples can be found in Appendix F.

Table 5

Parent and Child Code Distribution

Parent / Child Code	Files	References
1. AFFECT	20	566
DISGUST	14	45
FEAR, WORRY, CONCERN	18	252
FRUSTRATION, AGGRIVATION, ANNOYANCE	20	169
HAPPINESS, EXCITEMENT	18	70
SADNESS, DISAPOINTMENT	9	21
SURPRISE	7	9
2. COMMERCIAL PRESSURE	20	255
CORPORATE FAILURE NOT AN OPTION	19	79
CORPORATE PROTECTIONISM	15	38
MANIPULATION, PRESSURE ON LEGISLATORS	12	45
POLITICAL PRESSURE ON REGULATOR	13	47
PUBLIC IMAGE PRIORITIZATION	12	41
3. GAPS AND LACKS	20	812
EDUCATION OUTREACH	17	100
FUNDING AND FINANCE	13	32
MODELING CAPABILITY, DATA	17	86
PERSONNEL, WORKFORCE	14	50
REGULATIONS AND STANDARDS	20	182
TECHNOLOGY	17	64
TERMINOLOGY STANDARDIZATION	16	82
UNDERSTANDING AVIATION, ADVANCED AVIATION	20	216
4. HIGHEST PRIORITIES	20	736
CONSENSUS, CO OPERATION	18	123
DOMESTIC COMPETITION	5	11
GAINING COMPETITIVE ADVANTAGE	14	66
GLOBAL COMPETITION	10	27
INVESTORS PERCEPTION	18	91
PUBLIC PERCEPTION, EXPERIENCE	19	121
RETURN ON INVESTMENT	19	133
SAFETY	20	164
5. IDENTIFIED VERTIPORT PROBLEMS	20	1122
AIRCRAFT UNIFORMITY	20	133
AIRCRAFT VOTICIES	11	37
CYBER, PHYSICAL SECURITY, PRIVACY	9	29
FIRE RISKS, HAZARDS, CODES	7	22
LACK OF UNDERSTANDING OF VERTIPORT OPERATIONS	20	202
LOCATION OF VERTIPORT	20	257
LOW ALTITUDE AND MICRO WEATHER	16	58
MUNICIPALITY EQUITY AND ACCEPTANCE	14	80
NIMBYISM	3	4
NOISE	8	25
PHYSICAL OBSTRUCTIONS, OBSTICALS	15	67
ROTOR DOWNWASH, DISK LOADING	14	44
UNKNOWN RISKS	20	162
6. SAFETY CULTURE	20	301
FRICTION, MISMATCH IN SAFETY CULTURES	19	97
SEXISM	1	3
SILICONE VALLEY INNOVATION CULTURE	18	141
TRADITIONAL AVIATION CULTURE	15	56
7. STAKEHOLDERS PERCEPTIONS	20	579
AUTOMATION AND AUTONOMY ASSUMPTIONS	16	92
NOVELTY ASSUMPTIONS	20	235
RISK PERCEPTIONS AND ASSUMPTIONS	20	250
	840	8729

NVivo Matrix Code Hierarchy revealed the frequency hierarchy level of all Child Codes; 10 of the 47 child codes emerged with coding frequency scores of over 150. Table 6 presents the top 10 Child Codes with descriptors.

Table 6

Top 10 Child Code Frequency and Explanation

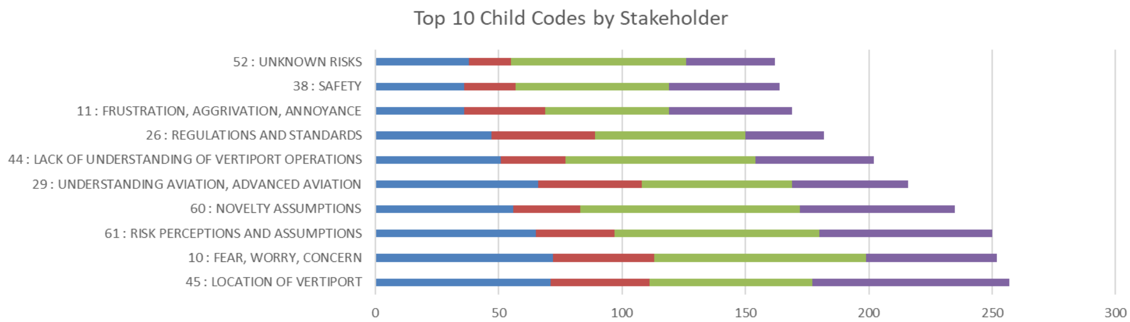
Top 10 Child Codes	Code Explanation
Location Of Vertiport	The participant discussed the location of the vertiport: the need for the vertiport to be profitable for the operator. This code is for participants who talk about the location of the vertiport, its viability, profitability, throughput, or usage. Also, if they mention they have concerns about safety with the physical location, it is also coded to safety.
Fear, Worry, Concern	Participant expresses an unpleasant or strong emotion caused by anticipation or awareness of potential danger operational safety and general safety concerns, e.g., "…*every time I see drones flying near a heliport I think, wow what a nightmare..."*
Risk Perceptions And Assumptions	Reflected in stakeholders' comments**, others are *not* considering risk,** higher risk or others don't understand the risk. Assuming others are 'ignorant, 'This code is for expressions where 'others don't appear to understand' or be thinking or knowing risk factors.
Novelty Assumptions	The participant indicates that this is a unique 'start-up' industry, and no one has done this before; the participant indicates they are in novel or new technology and make assumptions without having actual knowledge, data, or experience: "We can put through X aircraft per hour." Other Stakeholders are 'banking' on the assumptions these concepts will work.
Understanding Aviation, Advanced Aviation	Participants expressed that they or others don't have a good enough understanding of advanced aviation to make decisions. Uncertainty and lack of knowledge about Advanced Aviation.
Lack Of Understanding Of Vertiport Operations	Lack of understanding of how operations are going to be conducted at UAM vertiports. There is an absence of a shared understanding of aircraft performance, regulations, zoning, movement or throughput of aircraft movement, or numbers of takeoffs and landings per day or hour.
Regulations And Standards	Lack of regulations about vertiports and UAM operations. Lack of regulatory guidance and material.
Frustration, Aggravation, Annoyance	Participant expresses a sense or state of insecurity and dissatisfaction arising from unresolved problems or unfulfilled needs. *"There are so many other things to worry about, um, so it's pretty easy for me to stay up all night and get frustrated! – uhh and concerned…"*
Safety	Expressions of actions or efforts to / or show concern to protect against failure, breakage, or accident
Unknown Risks	The participant indicates that there may be unknown risks, or they don't know, or they recognize that there are risks they have not considered.

Frequency distribution of the top 10 codes shows that the individuals who worked for the Research and Development stakeholders comprised of NASA, NARI, and the NUAIR community displayed the most coding in the top 10ten child codes. The Research and Development stakeholder group also exhibited a greater frequency of *Fear, Worry, and Concern* coding and had a greater frequency of coding in the *Risk Perception* and *Novelty Perceptions* than of other stakeholders, along with significantly higher coding frequency for the recognition of *Unknown Risks, Safety,* and expressions of the *Lack of Understanding of Vertiport Operations*. The increased frequency of this Parent Code for this stakeholder group is unsurprising, considering they are at the forefront of much of the research addressing the industry's current problems.

Individuals who worked for Airport and Municipalities stakeholders indicated the highest frequency of child codes relating to the l*ocation of the Vertiport*. Individuals who worked for the Aircraft and Component Manufacturers (ACM) stakeholders exhibited the *least* code frequency in each of the top 10 child codes—notably less than half in recognizing *Unknown Risks* and *Novelty Assumptions*. Figure 21 shows these top 10 codes with code frequency across all the stakeholder groups.

Figure 21

Top 10 Child Codes and Stakeholder Distribution by Frequency.



	45 : LOCATION OF VERTIPORT	10 : FEAR, WORRY, CONCERN	61 : RISK PERCEPTIONS AND ASSUMPTIONS	60 : NOVELTY ASSUMPTIONS	29 : UNDERSTANDIN G AVIATION, ADVANCED AVIATION	44 : LACK OF UNDERSTANDIN G OF VERTIPORT OPERATIONS	26 : REGULATIONS AND STANDARDS	11 : FRUSTRATION, AGGRIVATION, ANNOYANCE	38 : SAFETY	52 : UNKNOWN RISKS
GOV	71	72	65	56	66	51	47	36	36	38
ACM	40	41	32	27	42	26	42	33	21	17
R&D	66	86	83	89	61	77	61	50	62	71
ACM	80	53	70	63	47	48	32	50	45	36

GOV ACM R&D ACM

Note: The complete list of Matrix Analyses for all coding is located in the Master Research Log.

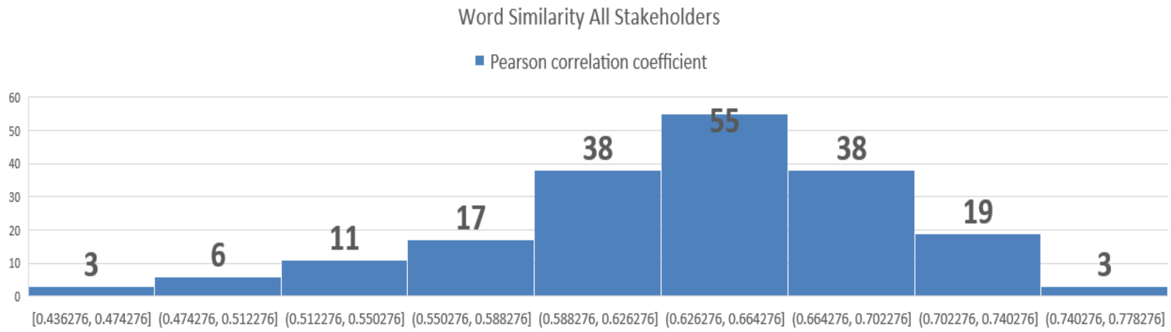
A Pearson correlation coefficient analysis of '*word* similarity' also called a 'similarity index', was calculated in NVivo, and the results were transferred into Microsoft Excel to create a histogram illustrating the commonality of word usage across all participants. Additionally, NVivo presented this information in a word tree cluster (dendrogram), which enabled the researcher to examine individual branches of word similarity used by the participants to gain deeper insights into the commonality of the language they were using in response to the questions in the instrument. Visualizing both the word tree (dendrogram) and the histogram supports the conclusion that shared language and, therefore, likely emergent themes are present within the data, supporting the idea that these themes are likely transferrable to the population of interest.

By leveraging NVivo's coding, querying, and statistical analysis capabilities, researchers can apply quantitative measures like Pearson's correlation coefficient to gain deeper insights into word similarity and patterns within qualitative data sets. For this study, Pearson's correlation analysis provided a visual depiction supporting the assumption of data adequacy. Pearson's correlation coefficient measures the strength and direction of the linear relationship between two variables; it is often used in qualitative research to ascertain the similarity of coding between coders where there is an established theoretical framework (Saldaña, 2021).

NVivo also calculates a similarity index between each pair of items (each pair of rows in the table) using the similarity metric selected (Pearson correlation coefficient (-1 = least similar, 1 = most similar). In this context, it can indicate how closely related or similar the usage of certain words (nodes) is across qualitative data. NVivo provides tools to perform this calculation directly from the matrix data. A coefficient close to +1 indicates a strong positive relationship (high similarity) between words, whereas a coefficient close to -1 indicates a strong negative relationship (dissimilarity). Coefficients near 0 suggest a weak or no relationship between the words. Normalization of data in qualitative research is not always mandatory; however, it can be highly beneficial in qualitative research, as it helps mitigate biases related to document lengths and overall word frequencies, leading to more accurate and meaningful interpretations of word relationships within qualitative data sets. Two tests for normality were conducted on the similarity index, the Kolmogorov-Smirnov[a] and Shapiro-Wilk tests for normality; the results are located in Appendix G. The tests revealed that normality was violated, likely due to the variable text length of the transcripts, this has been noted in the limitations section. Figure 22 presents the histogram developed from the population Pearson correlation coefficient in NVivo.

Figure 22

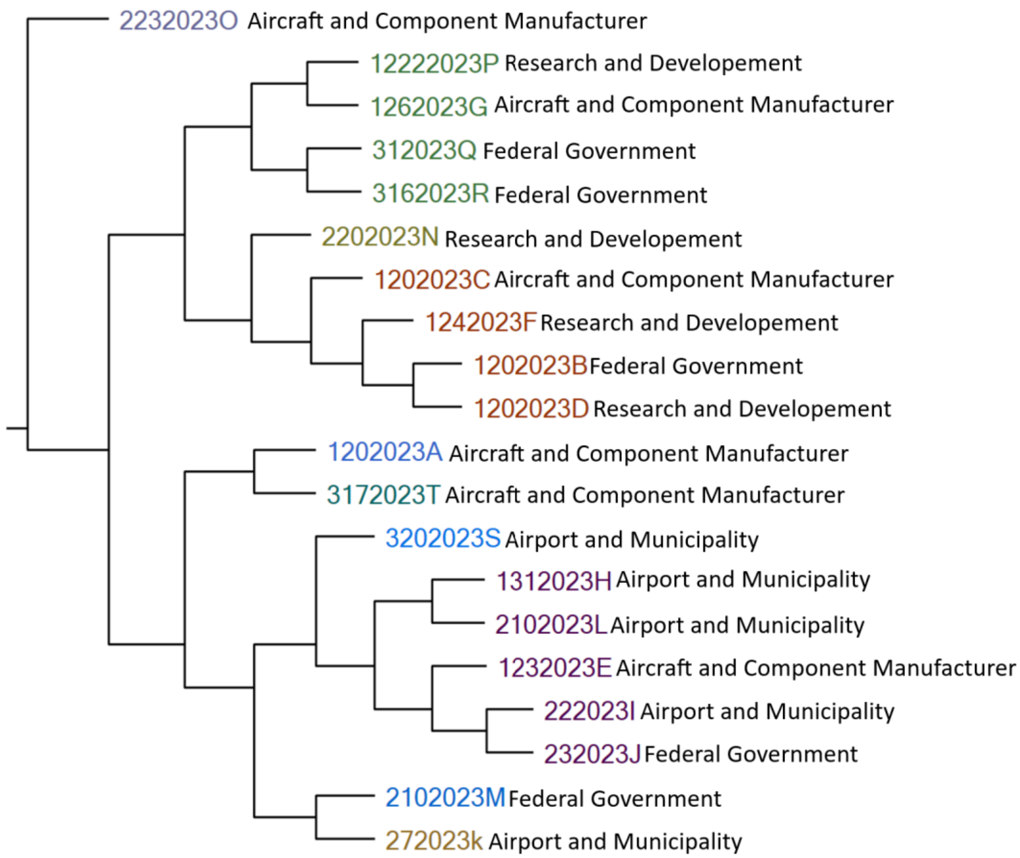
Participant Word Similarity.



While the histogram helps visualize the distribution of word similarity used within the sample frame, examining the word cluster or dendrogram shows individual participants' similarity in word usage and allows the researcher to contrast and possibly identify different participant perspectives. For example, the dendrogram in Figure 23 clearly shows Participant '**O**' (2232023O), an individual from the Aircraft and Component Manufacturing stakeholder group, who did not share word similarity with most participants. It is interesting to note that Participant 'O' was the oldest participant, a male reporting his age as greater than 80, and had distinctly unique perspectives on using hydrogen and the location and designs of UAM Vertiports. From a quantitative research perspective, this individual would likely be designated an 'outlier'; however, from the qualitative perspective, this participant's lived experience and opinions contribute to the rich content of the data and may stimulate reflection or further investigation by others. A stakeholder category has been added to each participant number on the NVivo dendrogram in Figure 23.

Figure 23

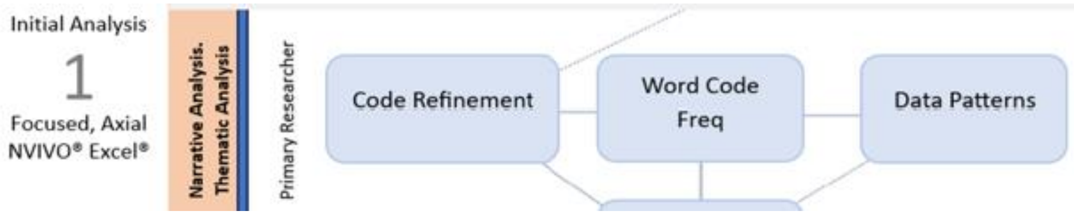
Dendrogram Word Similarity and Participant Stakeholder Category.



Summary of Findings Initial Data Analysis

This initial analysis step examined the data 'big picture,' the frequency, similarity, and distribution of word usage, and the consensus and establishment of the Parent and Child codes. It also assessed the role of independent coding in supporting qualitative validity and reliability and minimizing primary researcher bias. While this initial analysis has established the codebook, it also provides the starting point to investigate the prominent child codes and examine other factors like the values for positive or negative sentiment and the associated affective or emotive responses. Figure 24 below shows the position of the initial analysis within the whole analysis process.

Figure 24
Initial Analysis: Phase 1.



Next, the secondary analysis builds upon this initial analysis and examines the prominent Child codes from the participant narrative and the phenomenological aspects of *Sentiment* and *Affect*. Learning from the first phase of the analysis included the need to clarify and include detail in some of the code descriptions to reduce ambiguity for future researchers and increase replicability (previous example of security to clarify it relates to physical and cyber security). Additionally, the researcher was satisfied with the word code frequency analysis and the data patterns that will be discussed further later in the chapter.

Secondary Data Analysis

As discussed in Chapter II, emotions [affect] can be crucial in decision-making, and often influence affect the opinions and perceptions of individuals; therefore, all child codes under *Affect*, including (a) *Fear, Worry, Concern*, (b) *Frustration, Aggravation, Annoyance*, (c) *Disgust*, (d) *Sadness*, *Disappointment*, e) *Happiness*, *Excitement*, and (f) *Surprise* were included in the analysis of each participant transcript. Although *Affect* is a Parent code in this study, its purpose is to be a tool to analyze the lived experience being expressed by the participant, as is the inclusion of sentiment coding. The phenomenological perspective requires an analysis of codes that were co-coded with a Child Code descriptor for *Affect*, and the appropriately identified *Sentiment*; for example, participant perceptions and expressions of *Fear, Worry,* and *Concern* were often expressed with negative (-) sentiments (a sigh, or negative tone, or contextual narrative to support the participant's negative state of mind). Following is an excerpt from a participant narrative that includes *Fear, Worry, and Concern* and is also coded for moderately and very negative *Sentiment.*

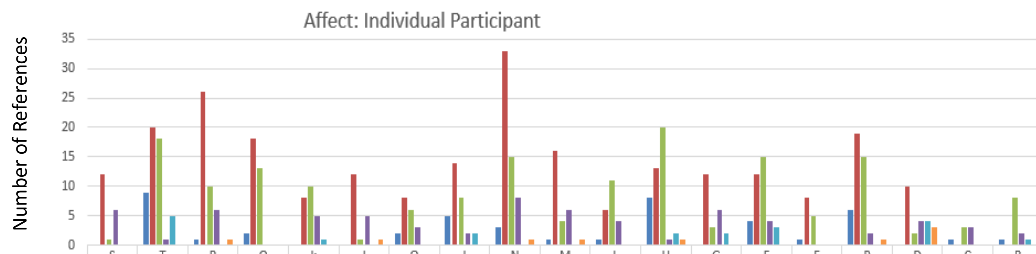
> …every time I see drones flying near a heliport I think, 'Wow wow what a nightmare.' So it's those types of things –you know people used to talk about flying drone bombs and is that what keeps you up at night, I I'm like 'Nope, that is'nothing – there's so many other things to worry about um so it's pretty easy for me to stay up all night and get frustrated – uah and concerned, but, the reality for most people that impacted is once the damaged is done, once you've burned the city, because you took money and built a vertiport that then couldn't be used - just for a press release there is an impact on that. And it will hurt all of us who are in the for the long haul not just chasing a press release or chasing quarterly return. (Participant P, Reference 4 - 0.63% Coverage).
>
> *Note:* In the above transcript, the reference tag means Participant P; it is the 4th reference to this particular code and represents 0.63 percent of the transcript.

Coding of *Sentiment* and *Affect* was essential to uncover emergent themes from the phenomenological perspective. NVivo Matrix code analysis revealed that all participants except C and B expressed *Fear, Worry, and Concern*; for these two participants, the most frequently coded emotion was *Fear, Worry, and Concern,* followed by *Frustration, Aggravation, and Annoyance*. Participant N (Research and Development) showed the highest frequency of both these codes, followed by Participant R (Federal

Government) and Participant P (Research and Development). Fifteen participants expressed *Happiness and Excitement*, which was surprising, as well as Participant N (who expressed the most *Fear, Worry, and Concern*). Figure 25 presents the results of the Matrix code inquiry for all child codes of *Affect* per individual participant, which are labeled by their alphabetical identifier.

Figure 25

Affect: Individual Participant



	S	T	R	Q	k	J	O	I	N	M	L	H	G	F	E	P	D	C	B
1 : DISGUST	0	9	1	2	0	0	2	5	3	1	1	8	0	4	1	6	0	1	1
2 : FEAR, WORRY, CONCERN	12	20	26	18	8	12	8	14	33	16	6	13	12	12	8	19	10	0	0
3 : FRUSTRATION, AGGRIVATION, ANNOYANCE	1	18	10	13	10	1	6	8	15	4	11	20	3	15	5	15	2	3	8
4 : HAPPYNESS, EXCITEMENT	6	1	6	0	5	5	3	2	8	6	4	1	6	4	0	2	4	3	2
5 : SADNESS, DISSAPOINTMENT	0	5	0	0	1	0	0	2	0	0	0	2	2	3	0	0	4	0	1
6 : SURPRISE	0	0	1	0	0	1	0	0	1	1	0	1	0	0	0	1	3	0	0

1 : DISGUST 2 : FEAR, WORRY, CONCERN 3 : FRUSTRATION, AGGRIVATION, ANNOYANCE 4 : HAPPYNESS, EXCITEMENT 5 : SADNESS, DISSAPOINTMENT 6 : SURPRISE

An excerpt from the transcript of Participant N captures some of the sources or manifestations of *Fear, Worry, and Concern* and associated coding with *Frustration, Aggravation, and Annoyance*. The following participant excerpt has not been altered to correct grammar.

> …and it's interesting to note that in the regulations that spell out those three categories, they don't define what 'objectionable' is. It's only when you go to the FAA's document that talks about heliport evaluation in the flight standards in the Flight Standards Information Management System (FSIMS) that it says 'unsafe to personnel in the aircraft and people on the ground' - so they're actually saying it's

objectionable, so they are saying it's unsafe, but the FAA does not have the legal authority to say NO…

…What is the paying public going to accept as a quality ride? So we get into 'G Loading' and we get into acceleration and deceleration not only in the horizontal but the vertical – and I see these trajectories that the OEMs are looking at using and I am like - NO one is ever going to want to get back on your aircraft! … – you know, I've had Mother Nature try to kill me, - on more than one occasion – so when I see an artist's rendition, I laugh and say … well that's really impressive, you defied at least three laws of physics that I have seen in the first three minutes so … good for you!! [expressed sarcasm].] (Participant N).

Participant N's excerpt transcript showed a small sample of [coded] *Concern and Worry*, a code seen in Figure 21, which appears frequently through participant data with coded *Frustration and Annoyance*. Further examination of distribution and relationship with these codes in Figure 25 reveals that the participants who expressed the most *Concern and Worry* were men, all of whom held master's or bachelor's college degrees. All but Participant H reported having over six years or more in traditional aviation roles. The following excerpt is an example of one participant's perspective showing moderate concern:

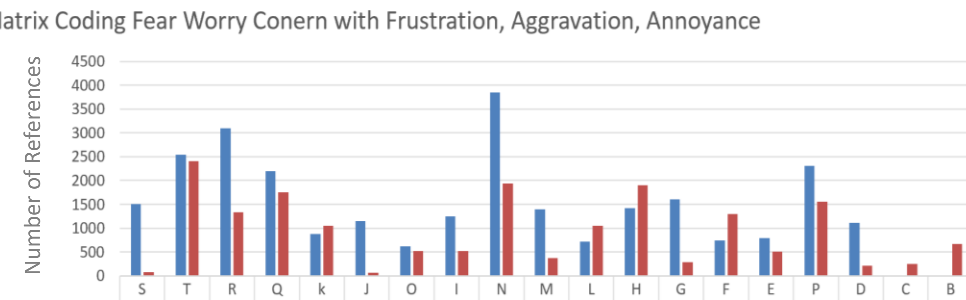
I think of the thing that keeps me up- is if companies are moving too fast towards this passenger service in and out of Vertiports, and we have a high number of accidents that happen in in the near term we're going to have accidents - everybody knows that it impossible to make an omelet without breaking eggs- and it's impossible to bring a new aviation concept into reality without some - some

> pitfalls, but if we jump straight to urban vertiports where the collateral damage from the loss of a vehicle could be a high societal loss, very high visibility - I think it'll be very difficult for the industry to remain on trajectory towards success. (Participant A, Reference 1 - 0.61% Coverage)

The data indicates a commonality of shared perspectives that produce worry, concern, fear, and shared experiences of frustration and aggravation; as the data was further analyzed, the sources of these experiences emerged. Theemerge. These results of matrix coding for *Fear, Worry, and Concern,* and *Frustration, Aggravation, and Annoyance* are presented in Figure 26.

Figure 26

Fear, Worry, and Concern, and Frustration, Aggravation, and Annoyance per Individual Participant



	S	T	R	Q	k	J	O	I	N	M	L	H	G	F	E	P	D	C	B
1 : FEAR, WORRY, CONCERN	1508	2536	3096	2191	880	1155	622	1249	3851	1394	713	1418	1605	748	786	2307	1117	0	0
2 : FRUSTRATION, AGGRAVATION, ANNOYANCE	78	2403	1337	1756	1048	68	521	525	1935	375	1046	1902	281	1291	509	1556	217	243	670

1 : FEAR, WORRY, CONCERN 2 : FRUSTRATION, AGGRAVATION, ANNOYANCE

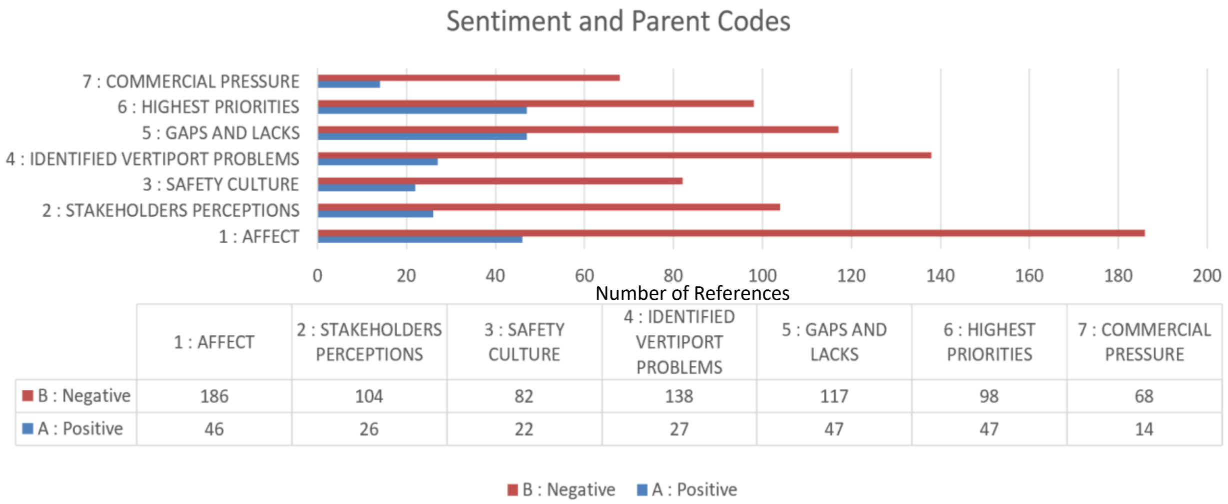
NVivo supports the coding of sentiment *magnitude* as either *moderately* or *very* and codes *direction* as either *negative (-)* or *positive (+)*. Further investigation of the frequency and context of *Affect* through matrix coding of *Sentiment* was needed to understand the magnitude of participants' *Worry* and *Frustration* and other aspects of *Affect*, which can be coded as negative or positive sentiment. It was noted that participant transcripts were often coded with both negative (-) and positive (+). Sentiments were co-coded with a child code of *Affect*.

Focused Axial coding allows for specific and more profound investigation of participant opinions and perspectives and supports phenomenological analysis of the lived experience and perceptions the participant is expressing. Unless the participant's tone was unmistakably positive or negative by language, tone of voice, a sigh, a laugh, or a gesture, it was not coded to *Sentiment* or *Affect* within the transcript. Throughout this chapter, participant excerpts are presented, illustrating sections of data coded with *Affect* and *Sentiment*.

Figure 26 presents the results of Axial Matrix coding for *Sentiment* in NVivo through each of the Parent Codes only. Macro analysis indicates that *Negative Sentiment (-)* was more frequently coded than *Positive Sentiment (+)*. The data showed that (-) sentiment was more frequently coded with W*orry, Concern, and Fear*, while *(+) Sentiment* was often coded with *Happiness and Excitement*. Interestingly, the participants who coded the highest for Happiness and Excitement (+) were often the same ones who coded the highest for *Worry, Concern, and Fear (-)*. Figure 27 presents additional insight into technical reasons for specific participant sentiment.

Figure 27

Matrix Coding Sentiment and Parent Codes



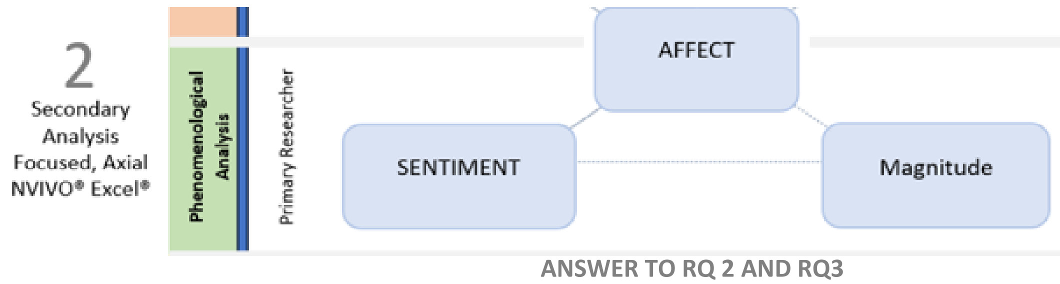
	1 : AFFECT	2 : STAKEHOLDERS PERCEPTIONS	3 : SAFETY CULTURE	4 : IDENTIFIED VERTIPORT PROBLEMS	5 : GAPS AND LACKS	6 : HIGHEST PRIORITIES	7 : COMMERCIAL PRESSURE
B : Negative	186	104	82	138	117	98	68
A : Positive	46	26	22	27	47	47	14

Summary of Findings Secondary Data Analysis

The secondary data analysis used Focused Axial coding using *Affect* and the magnitude and direction of *Sentiment* as the central tenets to understand the phenomenological perspective of the participant's expressions and experiences (Bazeley, 2013; Saldaña, 2021).

Figure 28

Secondary Analysis Focus: Phenomenological Perspective



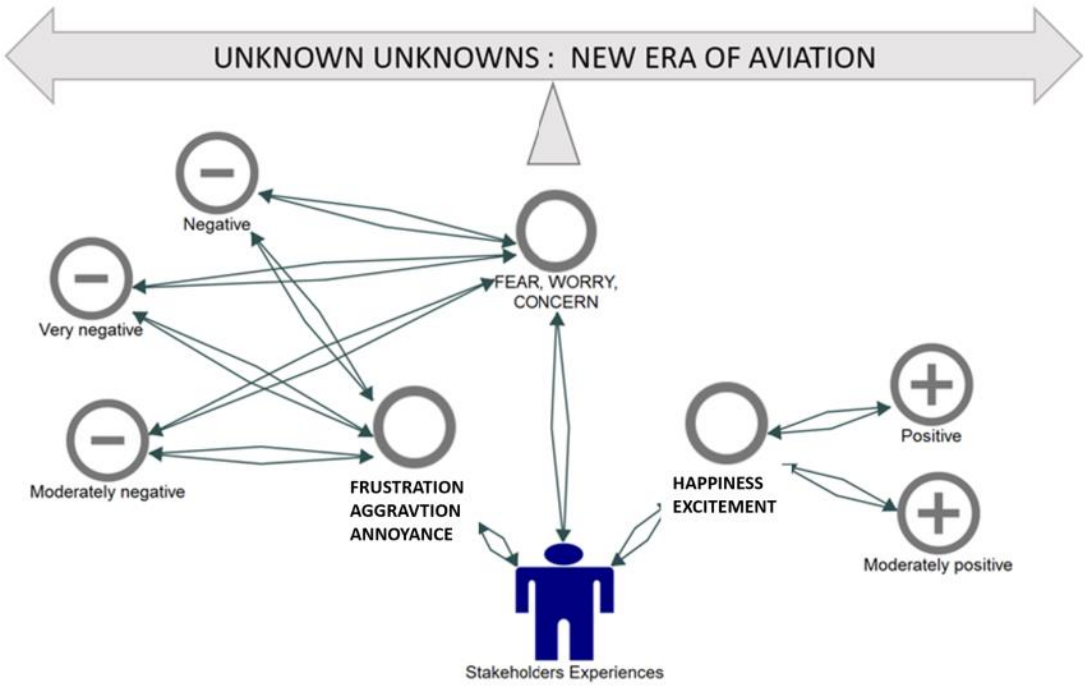
The results from frequency and matrix coding in NVivo, with presentation analysis in Excel, indicate results that many stakeholders reported frequent moderate (-) to very (-, -) negative *Sentiments* of *Worry, Concern, and Fear* while also expressing moderate to very negative *Sentiments* of being *Frustrated, Aggravated, and Annoyed*. Many negative and very negative sentiments are associated with immature technology, lack of regulations and standards, and the lack of knowledge and understanding of this new industry. However, many of the same participants also expressed moderately (+) positive sentiments, feeling *Happiness and Excitement* within the context of being at the forefront of this new emerging industry. These moderately (+) positive *Sentiments* were often expressed within the context of the excitement associated with conquering challenges and the experience of being at the forefront of a new era in aviation, thus providing the most likely and suitable answer for **RQ2** and **RQ3**. Some of this perspective is captured as Participant N describes their point of view:

> [laughs] it's been a fun ride, so, I really got involved within advanced air mobility when I started working as a consultant for [company x] back in 2017 – and then actually went internally to work for them about a year, then back externally for about a year, then they sold out to [company y]. – I say in this space, working in this space and living in this space 24/7 it's been fun, to meet new people, and build new relationships, and I always tell people that are gravitating to this, you know, - be involved, find out what niche you like. (Participant N).

RQ2 asked: *What* are the UAM vertiport stakeholders experiencing at the forefront of the industry-wide problem-solving challenge? While **RQ3** asked: *How* are the UAM vertiport stakeholders experiencing being at the forefront of the industry-wide problem-solving challenge? The answer to these RQs was captured in the data presented in this section and reproduced in the model depicted in Figure 29.

Figure 29

Summary Data Map: Affect and Sentiment Participant Experiences



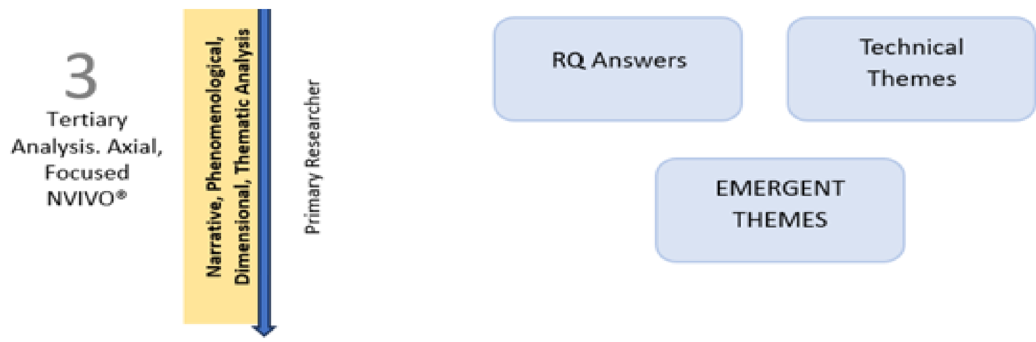
Tertiary Data Analysis

The tertiary data analysis takes the results presented so far and applies a focused approach to understand the specificity of participants' technical safety perceptions using the gathered data of *Affect* and *Sentiment*, for example, *Concern, Worry, and Fear, Frustration, Aggravation, and Annoyance* and the direction (-,+) and magnitude (moderately, very) of *Sentiment* expressed about these perceptions. Using the gathered data of *Affect* and *Sentiment* supports understanding the phenomenological experiences the participants perceive in their roles.

Further, this tertiary data analysis aims to uncover the commonality or diversity of these perceptions as they relate to the individuals and their stakeholder category. As previously discussed, *Affect* and *Sentiment* were used as tools in this study to understand and discover phenomenological themes from the narrative. The tertiary analysis examines the specific technical and potential elements contributing to emergent themes and answering the central research question. The reader is asked to recall the process analysis map; the tertiary analysis is the final phase of the analysis process, and it is depicted in Figure 30.

Figure 30

Summary Data Map: Tertiary Analysis



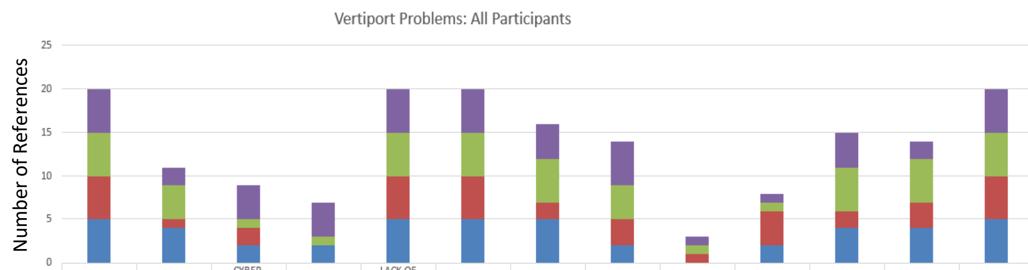
The tertiary analysis explores these technical elements, and possible emergent themes are explored using the six remaining codes, excluding *Affect* from Figure 24, including (a) *Identified Vertiport Problems*, (b) *Gaps and Lacks*, (c) *Stakeholder Perceptions* (general), (d) *Highest Priorities*, (e) *Safety Culture*, and (f) *Commercial Pressure*. The tertiary analysis begins with Identified Vertiport Problems. The Parent Code *Identified Vertiport Problems* has 13 nested Child Codes:

1. Aircraft Uniformity
2. Aircraft Vortices
3. Cyber, Physical Security, Privacy
4. Fire Risks, Hazards, Fire Codes
5. Lack of Understanding of Vertiport Operations
6. Location of the Vertiport,
7. Low Altitude and Micro Weather
8. Municipality Equity and Acceptance
9. Nimbyism (Not in My Backyard)
10. Noise
11. Physical Obstructions and Obstacles
12. Rotor Downwash, Disk Loading
13. Unknown Risks

The frequency of each of the 13 child codes for all participants is shown in Figure 31, with the *Location of the Vertiport* and a perceived *Lack of Understanding of Vertiport Operations* as the most coded perception, followed by the recognition of *Unknown Risks* and *Aircraft Uniformity*. It was surprising to the researcher that *Noise* and *Nimbyism* (Not In My Back Yard Expressions) were not more frequent or consistent throughout the participant data.

Figure 31

Matrix Coding Vertiport Problems: All Participants



	AIRCRAFT UNIFORMITY	AIRCRAFT VOTICIES	CYBER, PHYSICAL SECURITY, PRIVACY	FIRE RISKS, HAZARDS, CODES	LACK OF UNDERSTANDIN G OF VERTIPORT OPERATIONS	LOCATION OF VERTIPORT	LOW ALTITUDE AND MICRO WEATHER	MUNICIPALITY EQUITY AND ACCEPTANCE	NIMBYISM	NOISE	PHYSICAL OBSTRUCTIONS, OBSTICALS	ROTOR DOWNWASH, DISK LOADING	UNKNOWN RISKS
Airport and Local Municipalities	5	2	4	4	5	5	4	5	1	1	4	2	5
R and D	5	4	1	1	5	5	5	4	1	1	5	5	5
Aircraft and Component Manufacturer	5	1	2	0	5	5	2	3	1	4	2	3	5
Fed Gov	5	4	2	2	5	5	5	2	0	2	4	4	5

Matrix Coding Vertiport Problems: Stakeholder Analysis. The *Location of the Vertiport* code frequency captures participant expressions about the physical location of the vertiport. As illustrated by Figure 27, the physical *Location of the Vertiport* showed the highest code frequency, primarily amongst participants who belonged to the Local Municipalities (MUN) stakeholder category. The second most coded perception under the parent code was an expression of a general *Lack of Understanding* about vertiport operations. This perception appeared bi-directional; stakeholders admitted they did not fully understand and perceived others as not understanding vertiport operations. These perceptions were more frequently and consistently expressed by participants working for Research and Development (R&D) and Federal Government (GOV) stakeholder categories, which are primarily participants with a background in traditional aviation. Relating to these child codes, participants explained that there are no real vertiport operations that they can use to build models to understand operations. Participants expressed that the closest comparison is helicopter operations, which have many distinctly different operational and performance issues.

The Research and Development (R&D) and Federal Government (GOV) participants expressed moderately to very *Negative Sentiments* of worry and concern at their perceptions of *Lack of Understanding*, which were often concurrently coded with expressions of *Unknown Risks* while often explaining further context that they are very concerned with not only *Unknown Risks* but the complexity of known unknowns, and unknown-unknown risks. Participant T expresses the perception in the following transcript:

…one of the things that really bothers me here is that you have some companies articulating what they say is a safety message – and pushing to the highest levels of safety when they clearly don't know what they're talking about yet and advocating for requirements that - for instance, the Electric Vertical Take off and Landing (EVTOL) European Union Aviation Safety Agency (EASA) standards - pushing for a 10 to the -9th, rating across all these vehicles, saying that that will yield to the highest levels of safety, - When it is clear to me that will not be the case, and it is a fake way of trying to force safety inappropriately - and I'll say the reason for this is because that FDELL [fidelity] A and 10 to the -9th reliability only relates to the 15% of statistical accidents that cause fatalities from the vehicle perspective. The other 85% are operational causes - and so when you burden the aircraft with unrealistic requirements, and less is done on the operation side - and so again - my stance has been - why not make it 10 to the minus 11th or 10 to the minus 13th, people just pull this number out of thin air, and without analysis or the understanding what causes fatal accidents, which are primary operational issues. (Participant T, Reference 8 - 1.35% Coverage)

Aircraft Uniformity was the fourth most prominent code, as presented in Figure 31, each of the participants indicated this as a major concern relating to Vertiport Problems, expressed with moderate to very *Negative Sentiment* and *Affect* of *Fear, Worry, and Concern*. To provide context for the code, *Aircraft Uniformity* was described by participants as not limited to the uniformity of the aircraft design or performance but also how they will recharge, refuel, and address the associated ground handling logistics: Excerpt from Participant H:

> What are their operational limitations? Can they hover in ground effect, can they hover out of ground effect? Most of the ones most of them have wheels - most of them have wheels, so the assumption that I have is that they will be operating on the ground, like once they get to a landing area, or where they go to an area where they can take off from - What the aerodynamic characteristics, I will use the term fingerprint – what does that vehicle leave behind as it moves through a block of airspace. (Participant R Reference 16 - 0.62% Coverage)

Participant D expressed similar perspectives:

> I think that the nature of the motor flight multirotor how it's going to operate the transition- where we will see these hybrid vehicles where we transition from rotor to multi-rotors to fixed wing – to fly on wing, it's not quite defined. So we have to take this carefully I think right now we don't quite have enough information to

> just start building vertiports, or vertiplex – I don't we have enough information yet - I think we need some more research on the safety side. (Participant D, Reference 3 - 0.57% Coverage)

> So I do have some concerns there on our ability to recover especially in these higher risk transitions between the mode of flight. That worries me a bit – seems to me that is going to be a bit of a discouragement early on about the placement of some these vertiports and vertiplexes in these populated areas. (Participant D, Reference 6 - 0.38% Coverage)

Participant A provides similar and additional considerations, including using the acronym for CPNT, which relates to aviation communication of aircraft position, navigation routes and methods and timing of their flight path:

> …Geometry vs. vehicle performance of Traditional glideslope, or even "steep" approach (14 deg), will likely not be viable for high density ops- or Obstacle clearance, turbulence, and CPNT accuracy/capability will likely require more localized and more vertical trajectories to be the norm. This is diametrically opposed to the need for some aircraft to stay on wing as long as possible. (Participant A, Reference 8 - 0.62% Coverage)

Additionally, participants expressed concern and worry about the performance of the physical aircraft flight path and capability approaching and departing the vertiport. Participants in the Federal Government stakeholder category (GOV) expressed a high frequency of this code. They expressed concerns about the number of aircraft movements and how they will transition safely from takeoff and landing to the approach and departure phases of flight. An interesting finding was that participants from the Aircraft and Component Manufacturer stakeholder group (ACM) exhibited the second-highest frequency and consistency of this code; however, they expressed this concern and worry from the perspective of business viability and return on investment.

Physical Obstructions, *Rotor Downwash*, *Disk Loading,* and *Aircraft Vortices* were coded significantly more by participants with a traditional aviation and helicopter background in both Research and Development and the Federal Government stakeholder categories. Surprisingly, stakeholders from the Aircraft and Component Manufacturers (ACM) exhibited considerably less coding frequency across all child codes in this area and only slightly more than Municipalities (MUN), who were not from aviation backgrounds. Research and Development (R&D) and Federal Government (GOV) stakeholders also coded higher for concerns about *Low Altitude Environment and Micro Weather* factors.

A surprising finding was the significantly higher expression of concerns relating to *Fire Risks, Hazards, and Fire Codes* by the Municipality (MUN) stakeholders, particularly perceptions relating to the training and availability of first responders and the city's capability to deal with fire emergencies at Vertiports. This excerpt from participant H illustrates an example of these concerns (the transcript is <u>not</u> corrected for grammar or spelling. Additionally, the transcripts reflect habits of spoken English (e.g., fillers, like 'um'), and none were edited.).

> …I think another big component is fire safety – you know – Lithium-ion technology batteries right now - most fire departments don't put them out – [the fires] - they contain it. So from a containment standpoint - how - So it was on the

top of a garage - what is the fire rating of that top floor need to be - to ensure a fire can be contained ? and not cause a potential hazard to - you know - other operators and the people in the building and the vicinity? And quite frankly that's the big – unknown. *IS 8 feet of steel and concrete enough for an eVTOL to burn out ?* - because the chemicals used today aren't, aren't environmentally friendly - so those are maybe two components – that I think are ways my job impacts safety. (Participant H, Reference 1 - 0.88% Coverage)

My biggest Ah ha moment is really around fire safety, and it frightens me that – you know that Tesla's – that's a bad example - ALL electric vehicles have been driving around without a really legitimate solution to a battery fire – you know – and thankfully they are on the ground! so what happens if - God forbid – something happens in the air ? you know. That – I am surprised that the government hasn't required more R&D into safety solutions for lithium-ion battery technology. (Participant H, Reference 5 - 0.59% Coverage)

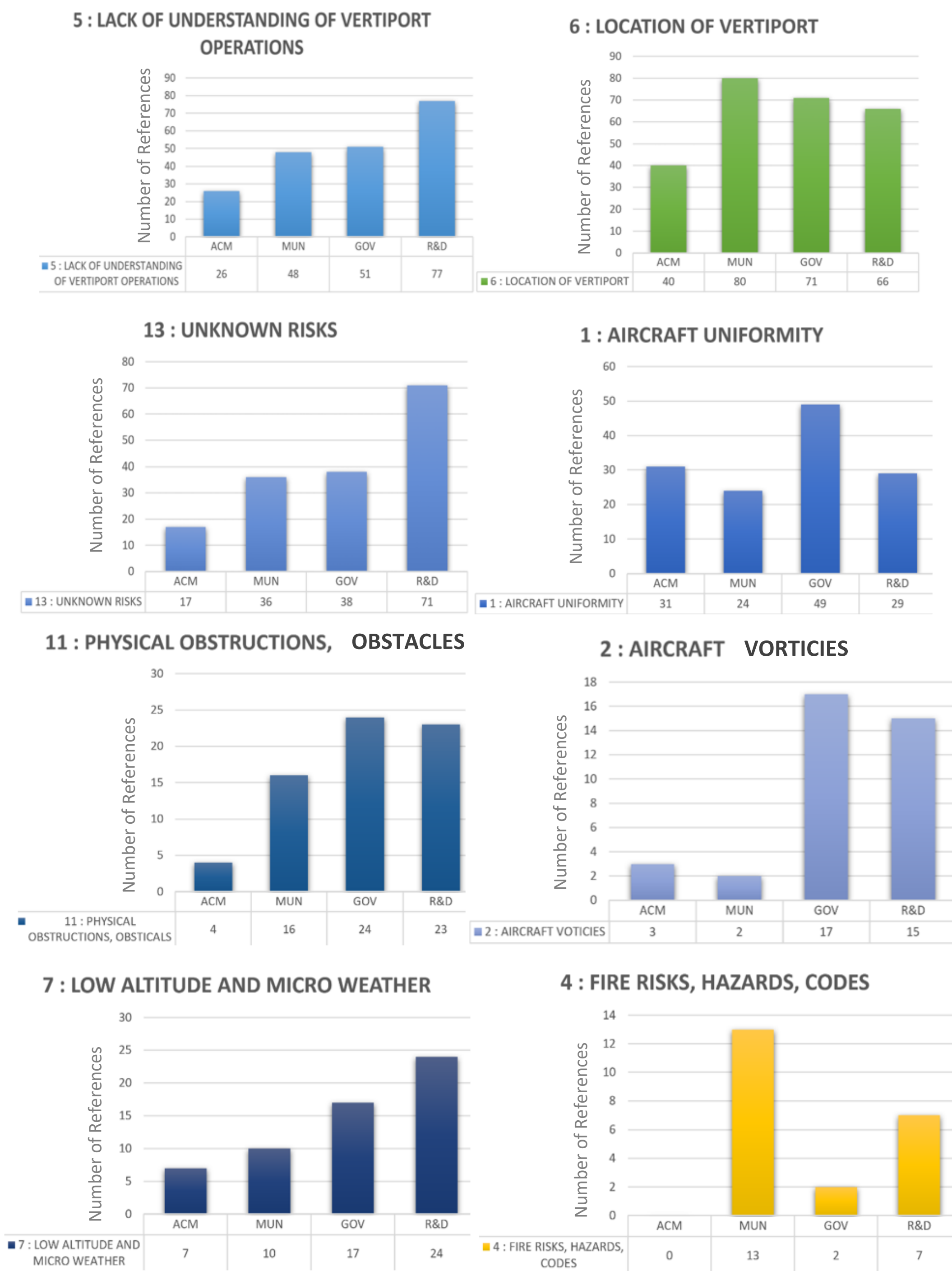
From an asset standpoint, as far as equipment and personnel to respond to an accident or respond to an emergency – but then if I decide to put that same infrastructure on top of a building – what's that look like? And that's I think one of the biggest challenges – how do you deal with an aircraft that does have a fire?, and that does have a lithium-ion battery overtemp and or runaway – and what apparatus needs to be in place to deal with that? Challenging because that standard traditional foam that we use today for heliports will not work for lithium-

> ion batteries, it’s a totally different animal and we’re still working all those out. (Participant N, Reference 4 - 0.75% Coverage)

Additionally, the MUN stakeholders expressed concern and worry with moderate and very negative sentiments about the availability of resources and the lack of appropriate building codes needed to handle such emergencies. Figure 32 shows some specific stakeholder perceptions of *Vertiport Problems* by stakeholder category.

Figure 32

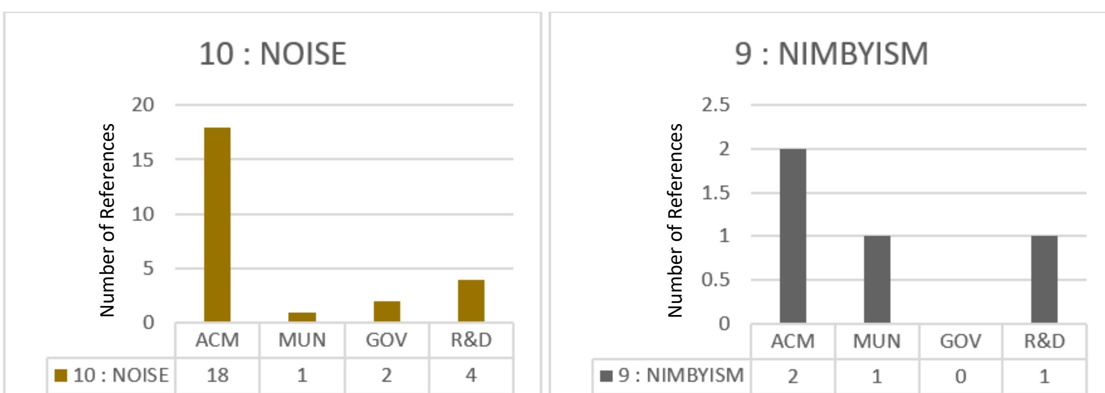
Matrix Coding Vertiport Problems: Stakeholder Category



The data revealed the analysis of child code frequency of *Noise* and *Nimbyism* (Not In My Back Yard), which appeared with the least measure of the magnitude of (-) *Sentiment* and frequency of *Concern, Worry, and Fear* than the other technical and performance orientated child codes across the whole stakeholder group. Although *Noise* and *Nimbyism* were the lowest on frequency and sentiment, it was interesting to see that the Aircraft and Component Manufacturers (ACM) expressed this concern significantly more than the stakeholders in other groups. Further, it was surprising that the Municipality (MUN) stakeholder group expressed the least concern for *Noise* and considerably less, but equal to the Federal Government (GOV) for *Nimbysim.* This result may indicate that stakeholders in the Municipality category are more familiar with the concept of *Nimbyism* but may not fully understand the potential *Noise* signatures of the eVTOL aircraft. Figure 33 provides the results of the stakeholder breakdown for *Noise* and *Nimbyism*.

Figure 33

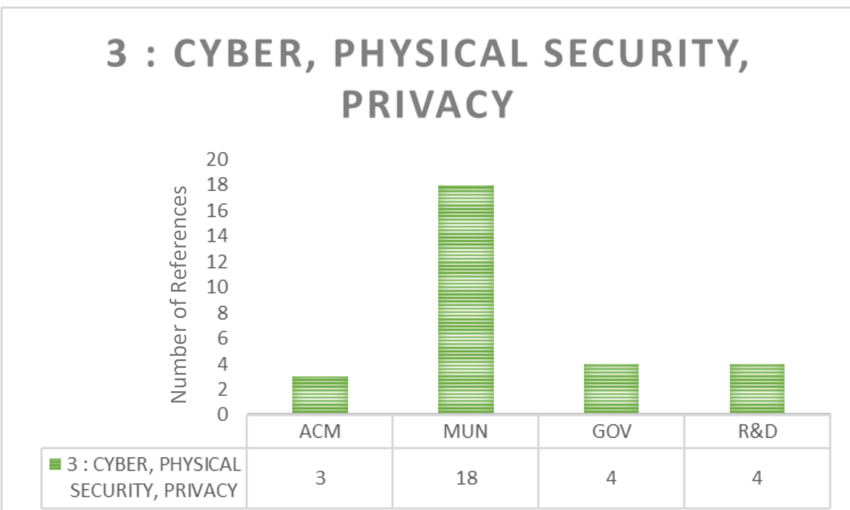
Matrix Coding Noise and Nimbyism Stakeholder Breakdown



In another matrix analysis, the data indicated a divergence of perceptions where ACM stakeholders were coded significantly more frequently for *Cyber, Physical Security, and Privacy* concerns. These perceptions were often expressed as not only the physical security of the vertiport but also included explanations of being concerned about human interference and nefarious activities or even nuisance and poor behavior on flights. Other concerns from the ACM stakeholder category included animal control, concealed weapons, hijacking, and other matters handled by the Transport Security Administration (TSA) or local law enforcement. Surprisingly, this was the only stakeholder group that indicated they were collaborating with the TSA on such matters. Figure 34 presents the results of the *Cyber, Physical Security, and Privacy* coding.

Figure 34

Matrix Coding Cyber, Physical Security, and Privacy Stakeholder Breakdown



Parent Code: *Gaps and Lacks*. Parent code *Gaps and Lacks* were also a prominent parent code for participants who expressed affect of *Worry, Concern, and*

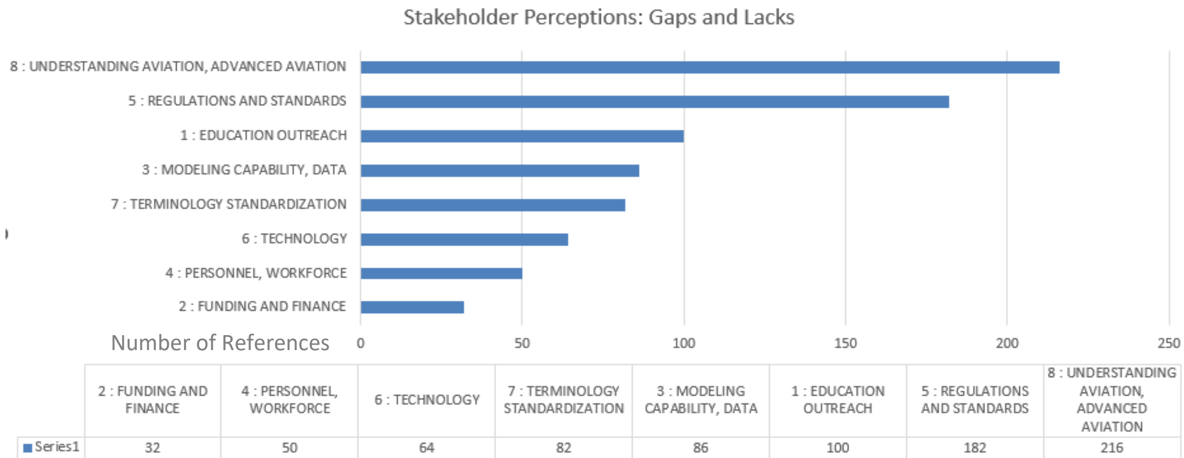
Fear, and negative (-) and very (-,-) *Sentiments. Gaps and Lacks* are expressions of a lack or something missing that the participant has identified and expressed in the transcripts as required to move forward with their decision-making and tasks related to their roles within their stakeholder category. There were eight child codes under this parent code, and they include the following list:

1. Education and Outreach
2. Funding and Finance
3. Modeling Capability and Data
4. Personnel and Workforce Talent
5. Regulations and Standards
6. Technology
7. Terminology and Standardization
8. Understanding Advanced Aviation

The most frequently coded *Gaps and Lacks* were the child codes of *Understanding Advanced Aviation*, which encompassed the perceptions that *others* and the self don't understand aviation and advanced aviation. Gaps and lacks associated with *Regulations* were the second highest code frequency, followed by *Education and Outreach Gaps,* and the lack of *Modeling and Data* about vertiports was also present in the data related to gaps and lacks. *Terminology and Standardization* were coded higher than *Technology* gaps, followed by *Personnel and Workforce* gaps. *Funding and Finance* were coded the least within this parent code. Figure 35 presents the results from stakeholders' perceptions of *Gaps And Lacks.*

Figure 35

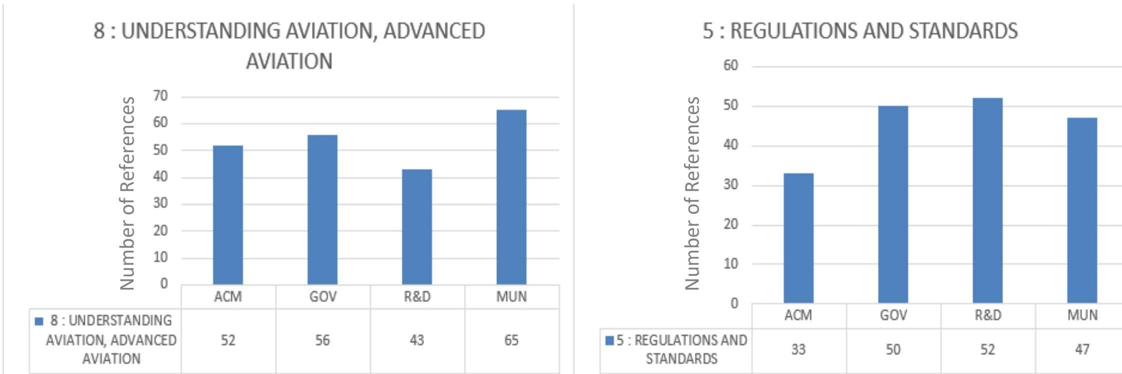
Matrix Coding All Stakeholder Perceptions of Gaps and Lacks



The results from the focused analysis of the subcodes under *Gaps and Lacks* revealed more commonality of participant perspectives rather than significant differences or divergences related to the general *Lack of Understanding of Aviation, Advanced Aviation*, and a general lack of *Regulations and Standards.* The results of this analysis likely point to the shared perception and opinions that a general lack of government regulations and industry standards is causing concern and worry among participants in all stakeholder groups. Figure 36 presents these findings in matrix coding of these two child codes across all stakeholder categories.

Figure 36

Child Codes: Lack of Understanding Advanced Aviation, and Regulations and Standards Gaps: Stakeholder Breakdown

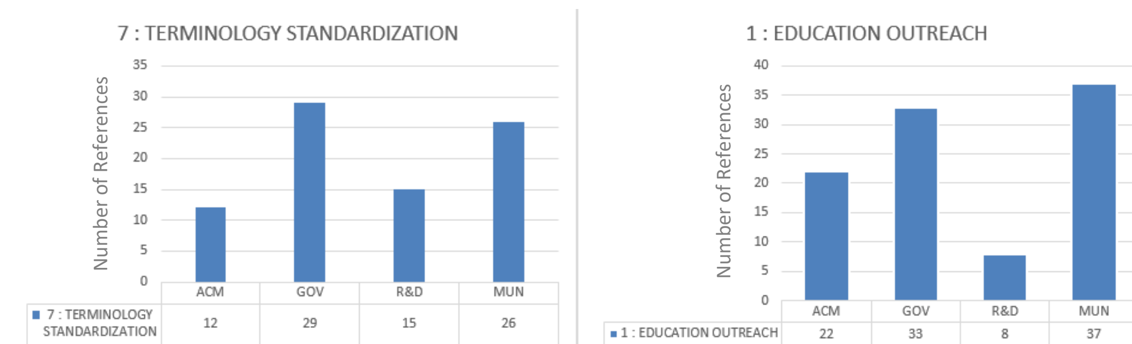


While there was uniformity in the shared perceptions of Affect and Sentiment in the general lack of understanding of *Aviation and Advanced Aviation*, the data indicated a divergence between the stakeholder categories, related more specifically to *Terminology Standardization*, which refers specifically to standardization terms and concepts published by standards bodies and government. Additionally, *Education and Outreach* refers to specific efforts by the industry and government in providing formal educational and outreach programs. In this child code, the Federal Government (GOV) and Municipalities (MUN) were coded more frequently and consistently as having *Worry, Concern, Fear,* and Negative *Sentiment*. This result seemed reasonable as stakeholders in the MUN category include vertiport designers and developers who work closely with the local governments and communities; some have experience in civil engineering and urban planning and considerable experience with local, state, and tribal governments that will likely have to host the Vertiport.

Related to these stakeholder perceptions, in the Municipality (MUN) and Federal Government (GOV), stakeholder categories were similarly coded with expressions of perceived lack and gaps of *Terminology Standardization* and *Education and Outreach* concerns. Notably, stakeholders in the Municipality (MUN) category expressed higher levels of Affect and Negative Sentiment [concerns] about the lack of *Education and Outreach. In contrast*, Federal Government stakeholder participants expressed more perceptions and opinions [concerns] about the lack of *Terminology Standardization*. This finding seems reasonable as Federal Government stakeholders rely more on specific and published terminology and standardization for implementing performance-based regulations. Figure 37 illustrates this divergence of perception, opinions, and concerns.

Figure 37

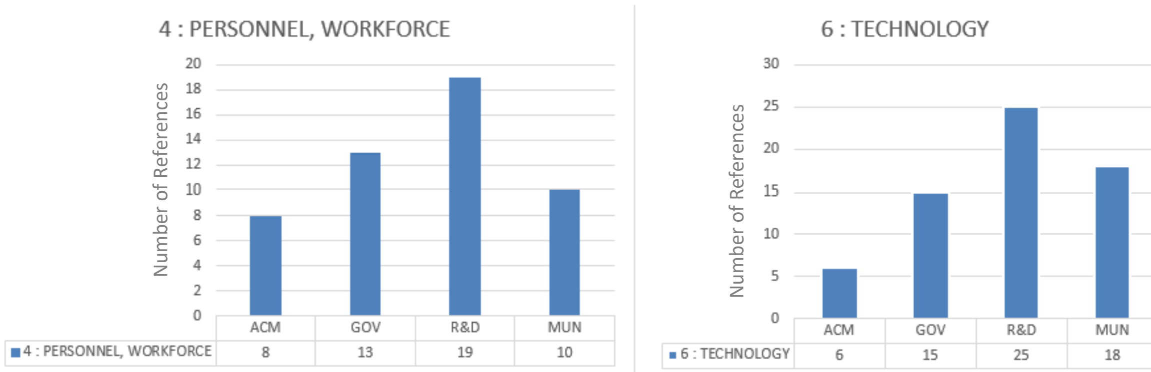
Child Codes: Terminology Standardization, Education and Outreach Gaps: Stakeholder Breakdown



According to the Nvivo analysis of the data code frequency, a divergence of perceptions and opinions also revealed the Research and Development (R&D) stakeholder category expressed more frequent perceptions about *Workforce, Personnel* gaps, and lacks than other stakeholder categories; also, this category exhibited the highest levels of perceptions of gaps and lack in *Technology*. Conversely, examining the data from these two child codes, Aircraft and Component Manufacturers (ACM) seem to express the least concern over lacks and gaps in *Personnel, Workforce, and Technology*.

Figure 38

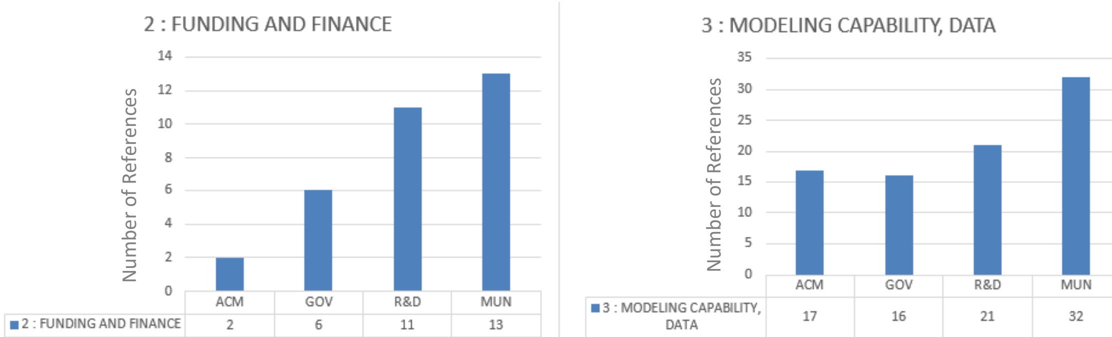
Child Codes: Personnel, Workforce and Technology Gaps and Lacks: Stakeholder Breakdown



Finally, the tertiary analysis of *Gaps and Lacks* used Matrix Coding to examine *Funding and Finance* and *Modeling* [data] *Capability* perceptions of the stakeholder categories; a similar pattern emerged in the data, indicating that Municipality (MUN) stakeholders expressed more frequent concerns about the lack of modeling capability and data around real-time vertiports operations, closely followed by Research and Development (R&D) stakeholders. An interesting finding was that the Aircraft and Component Manufacturers (ACM) scored lowest on the *Funding and Finance* child code while expressing more perceptions of *Commercial Pressure*, which will be discussed later in this chapter. Figure 39 presents stakeholder perceptions of *Gaps and Lacks Funding and Finance* and *Modeling Capability Data*.

Figure 39

Gaps and Lacks of Funding and Finance, and *Modeling Capability, Data*.



Parent Code: Safety Culture. Safety culture refers to the attitudes, behaviors, beliefs, values, and practices within an organization that prioritize or fail to recognize safety as a core value (Helmreich & Merritt, 2019; Reason, 1990; Stolzer, 2017; Stolzer et al., 2011). Child codes within Safety Culture include (a) *Friction, Mismatch in Safety Cultures*, (b) *Sexism*, (c) *Silicone Valley Innovation Culture*, and (d) *Traditional Aviation Culture*. The reader should note that these are not formal definitions of safety culture; instead, they are descriptors of the predominantly expressed perspectives of participants contained within the transcripts. Further, sexism was only coded within one female participant's transcript. While not the intention of this research, future studies could consider examining this topic in more detail. The following is an excerpt from the female participant that describes their experiences as they relate to the code of *Safety Culture*:

> …Personally though, - I think that being a woman in this industry is very – it's ahhh *not* the most fun (Reference 2 1.05%Coverage) - it leaves much to be desired from that perspective – because there's a bit of an echo chamber, - and it's echo chamber of a very kind of - it's kind of an intersections of very tech/

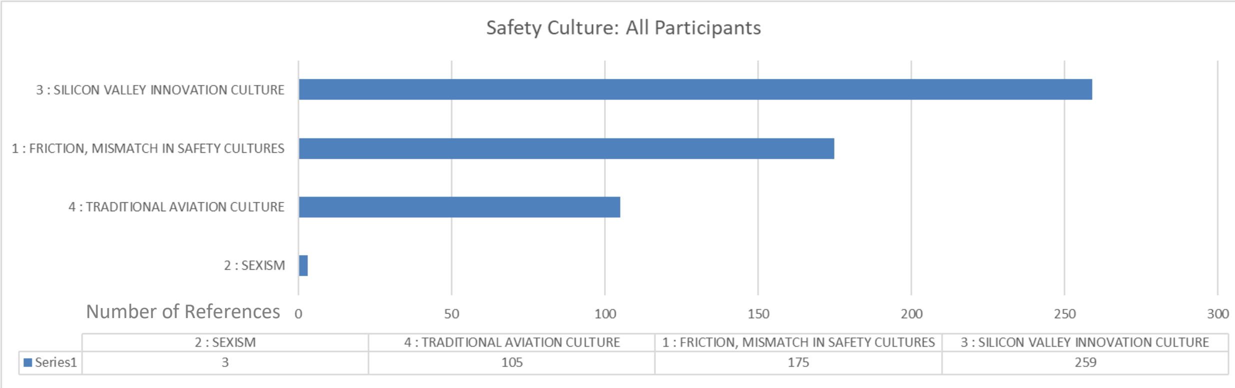
aviation/ aerospace, and then I work at the real estate side of all of that right. All of those are very male-dominated industries - and I feel the lack of diversity for sure. – So it's exciting, but it does feel like a lot of pressure, - you know there is a lot of money at stake, people have put up a ton of money - and so there is just a lot of pressure overall, I think - dealing with an industry like this – [pauses] and – (Reference 1 - 0.17% Coverage).

- So, you know, - I get a lot of attitude, there's a lot of Ego – you know, and granted, I worked in (redacted to preserve anonymity) and government, and that's true of a lot of sectors I've worked in – but yeah, a lot ego in both Tech and Aerospace – and so it can be a lot to manage. [pauses] – and I don't know if that's going to help adoption if you are trying to reach – sort of a mass market, I think we have to change the attitude around – you know – around the industry. (Reference 3 - 0.78% Coverage)

Sexism may be worthy of future investigation; however, within the scope of Safety Culture, it was co-coded with *Silicon Valley Innovation Culture*. The most frequently coded Safety Culture Child Code was *Silicon Valley Innovation Culture,* followed by coding referring to the *Friction and Mismatch Between Cultures* (between the *Silicon Valley Innovation* and *Traditional Safety Culture*). Figure 40 presents the results of the matrix code inquiry of Safety Culture Child Codes.

Figure 40

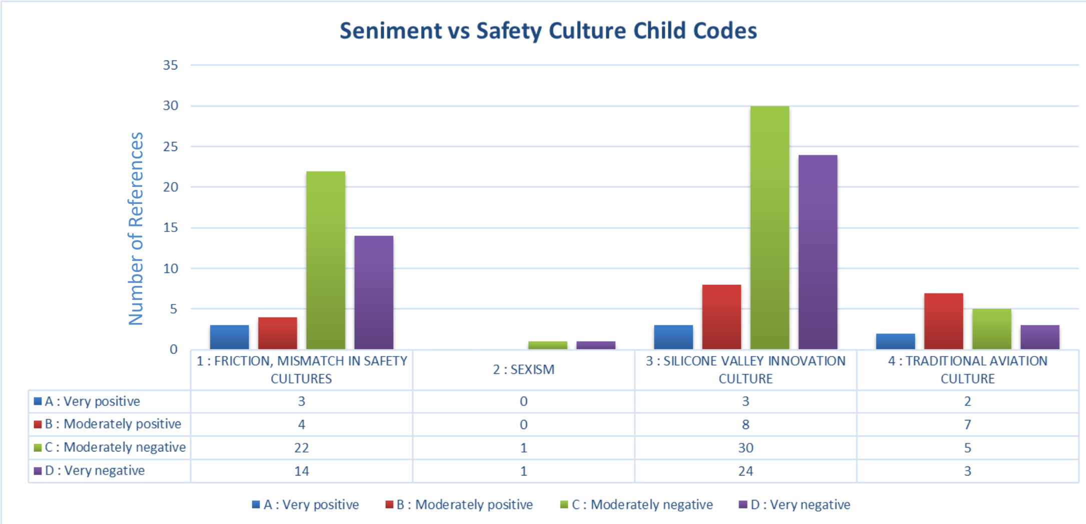
Safety Culture Child Codes: All Participants



Silicon Valley Innovation Culture describes the innovative and competitive spirit that is predominantly characteristic of high-tech companies; this code descriptor was used because many innovative companies are located in California. Of all the coded data for safety culture, 17% of the coding represents positive and very positive sentiment, reflecting some positive participant expressions that innovation is key to the emerging industry; however, 83% of the coding references indicated moderately (-) and very (-,-) negative sentiment towards *Silicon Valley Innovation Culture*, expressing affect of *Worry, Concern and Fear* from stakeholders who perceive that this is a culture that includes a lack of understanding of the potential known risks, and the presence of unknown risks and commercial pressures such as prioritizing profit and corporate competition over safety. Figure 41 presents the findings from Matrix Coding in NVivo® exploring Safety Culture Child Codes with Sentiment.

Figure 41

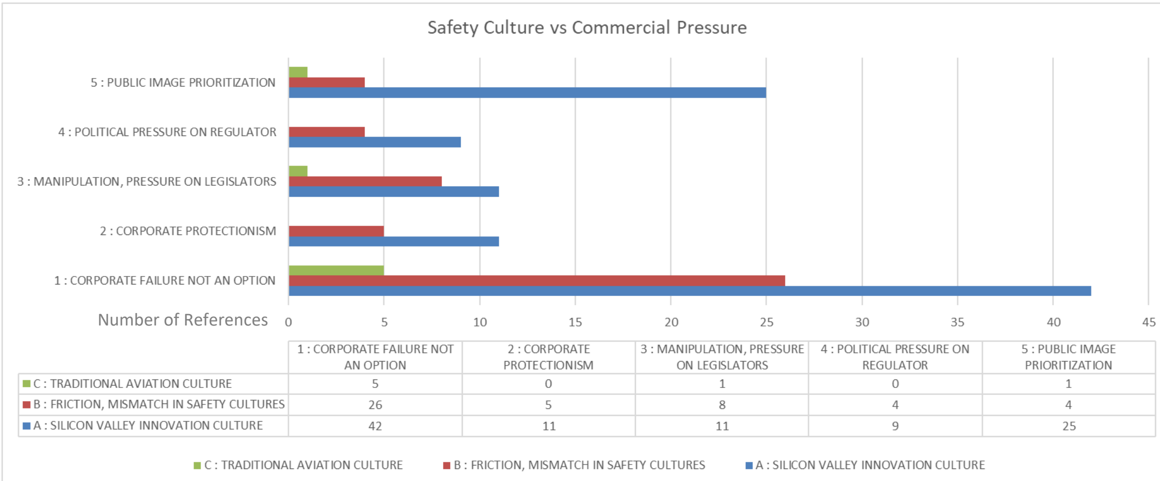
Safety Culture Child Codes with Sentiment



Safety Culture is a highly complex phenomenon (Helmreich & Merritt, 2019; Orlady & Orlady, 1999; Reason, 1990) worthy of considerably more analysis than the scope of this study, and it is therefore interesting that multiple matrix analyses of safety culture child codes were also overlapping and co-coded with child codes of *Commercial Pressure*, and *Highest Priorities*, and general *Stakeholder Perceptions of the Industry*. Therefore, *Safety Culture* and, more specifically, a new generation of innovation safety culture is a theme that will be discussed further in Chapter V. Figure 41 presents a matrix coding analysis of *Safety Culture and Commercial Pressure*. Figure 42 shows the matrix coding analysis *of Safety Culture and Highest Priorities*, and Figure 43 illustrates the matrix coding of *Stakeholder Perceptions of Industry and Safety Culture*.

Figure 42

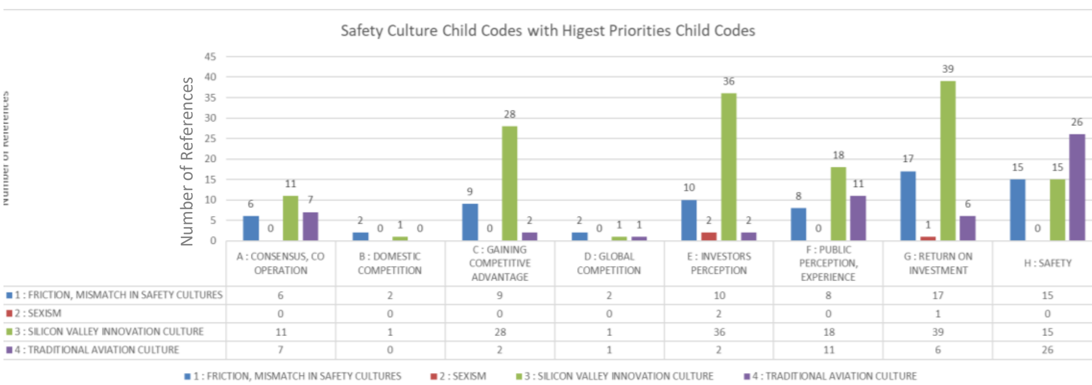
Safety Culture Child Codes with Commercial Pressure Child Codes



	1 : CORPORATE FAILURE NOT AN OPTION	2 : CORPORATE PROTECTIONISM	3 : MANIPULATION, PRESSURE ON LEGISLATORS	4 : POLITICAL PRESSURE ON REGULATOR	5 : PUBLIC IMAGE PRIORITIZATION
C : TRADITIONAL AVIATION CULTURE	5	0	1	0	1
B : FRICTION, MISMATCH IN SAFETY CULTURES	26	5	8	4	4
A : SILICON VALLEY INNOVATION CULTURE	42	11	11	9	25

Figure 43

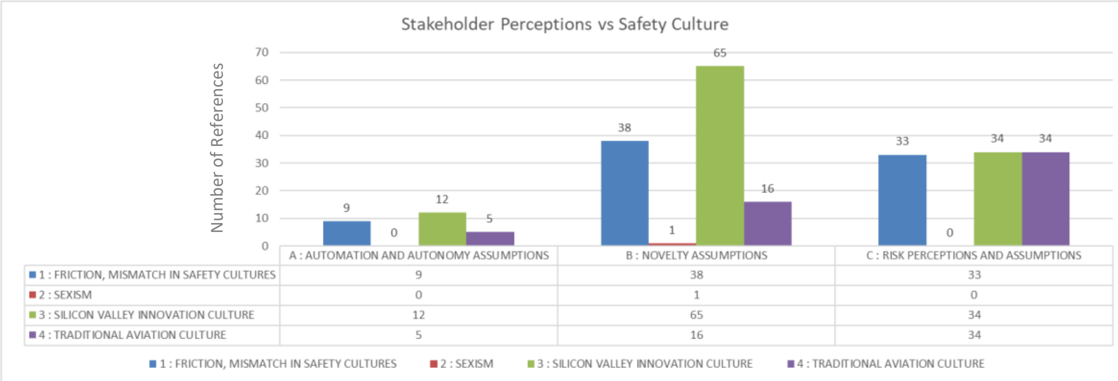
Safety Culture Child Codes with Highest Priorities Child Codes



	A : CONSENSUS, CO OPERATION	B : DOMESTIC COMPETITION	C : GAINING COMPETITIVE ADVANTAGE	D : GLOBAL COMPETITION	E : INVESTORS PERCEPTION	F : PUBLIC PERCEPTION, EXPERIENCE	G : RETURN ON INVESTMENT	H : SAFETY
1 : FRICTION, MISMATCH IN SAFETY CULTURES	6	2	9	2	10	8	17	15
2 : SEXISM	0	0	0	0	2	0	1	0
3 : SILICON VALLEY INNOVATION CULTURE	11	1	28	1	36	18	39	15
4 : TRADITIONAL AVIATION CULTURE	7	0	2	1	2	11	6	26

Figure 44

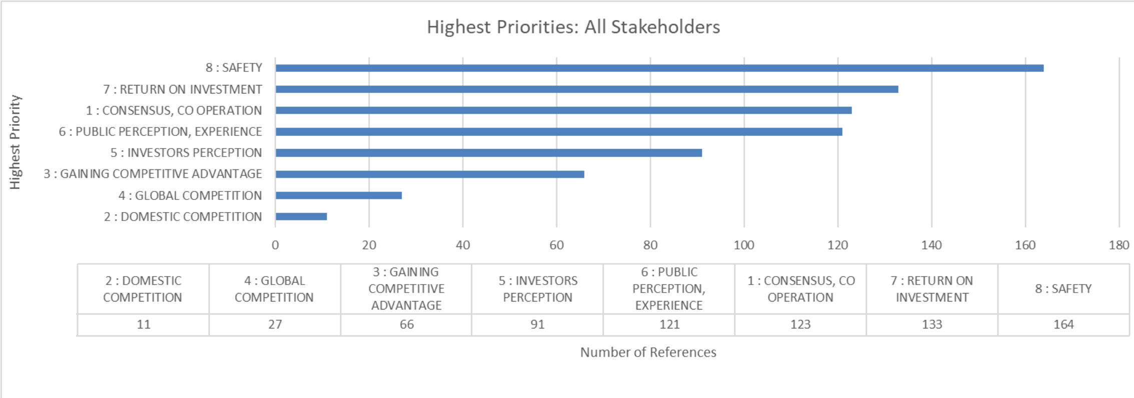
Stakeholder Perceptions vs Safety Culture Child Codes



Parent Code: *Highest Priorities*. The parent code's *Highest Priorities* include expressions of something given or meriting attention before competing alternatives within the stakeholder's objectives and goals within their role. Eight child codes are nested under the *Highest Priorities*, including safety, *Return On Investment, Consensus, and Cooperation, Public Perception and Experience, Investor Perception, Gaining a Competitive Advantage, Global Competition, and Domestic Competition.* The rationale or descriptor for each child code was presented earlier in Table 6. The findings of this analysis indicated that safety was expressed as the number one priority by most participants, followed closely by delivering a *Return on Investment*. The results of NVivo matrix coding and Excel analysis of Highest Priority Child Codes are presented in Figure 45.

Figure 45

Highest Priorities: All Child Codes



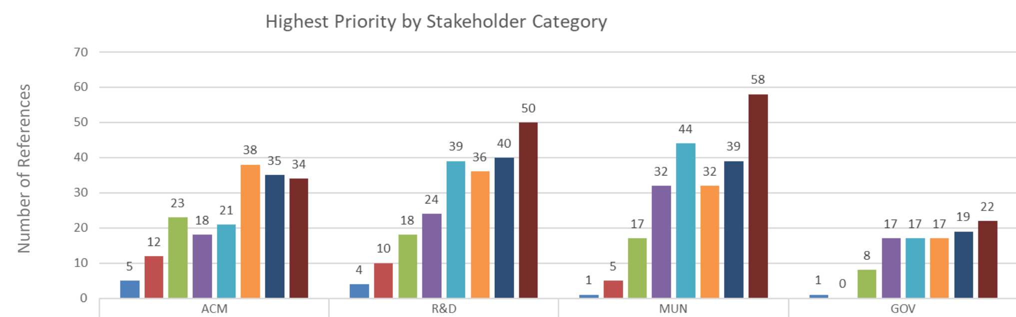
Additional analysis revealed some surprising results. The stakeholder category expressing the most perspectives that coded safety as their highest priority was the Municipality category (MUN), followed closely by *Public Perception and Experience*, although participant N from Research and Development (R&D) indicated the highest coding, and most specific expressions for safety being their highest priority:

> …So the things that caused accidents over the history of man, they're still going to be the things that cause accidents in the future. So paying attention to history and learning from past mistakes is a great guide and weathervane for what we are trying to accomplish in the future. (Participant N, Reference 11 - 0.24% Coverage)
>
> There will definitely be idiosyncrasies and that's where we do the research and development to vet those and figure out what those are – but not paying attention to history – that's – just – you are doomed to failure in my opinion. (Reference 10 of 22 - 0.30% Coverage, Participant N, R&D category)

The stakeholders in the Aircraft and Component Manufacturers (ACM) category coded more frequently for seeking cooperation and consensus as their highest priority, which was surprising as results of the *Commercial Pressure* parent code indicated they coded higher for codes of protecting their intellectual property and gaining a competitive advantage. Figure 46 presents the *Highest Priority* child codes by stakeholder category.

Figure 46

Highest Priority Child Codes by Stakeholder Category.



	ACM	R&D	MUN	GOV
2 : DOMESTIC COMPETITION	5	4	1	1
4 : GLOBAL COMPETITION	12	10	5	0
3 : GAINING COMPETITIVE ADVANTAGE	23	18	17	8
5 : INVESTORS PERCEPTION	18	24	32	17
6 : PUBLIC PERCEPTION, EXPERIENCE	21	39	44	17
1 : CONSENSUS, CO OPERATION	38	36	32	17
7 : RETURN ON INVESTMENT	35	40	39	19
8 : SAFETY	34	50	58	22

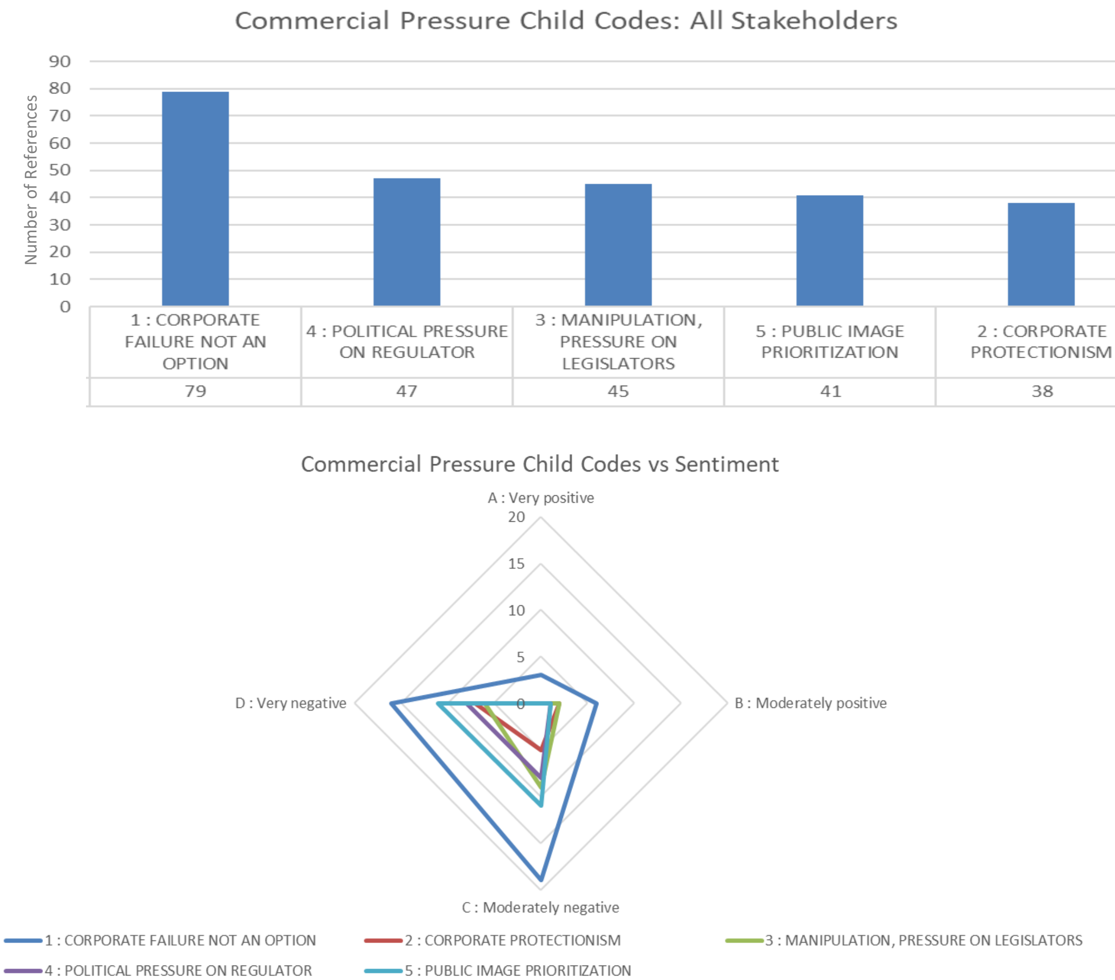
Parent Code: *Commercial Pressure.* The *Commercial Pressure* parent code in this study is a descriptor of the general and implied pressure organizations place on their representatives to maximize profits and minimize costs or gain perceived leadership and relevance within the industry; it differs from the more specific code of *Return on Investment*. The child code in *Highest Priorities*, *Commercial Pressure* encompasses more general expressions of a participant's perception, for example, pressure to reach throughput and service delivery, need to assert competitive dominance, emphasis on pubic messaging, “aspirational renditions” and social media posts, protecting intellectual and corporate interests and gaining an advantage through political and legislative pressure. An excerpt from participant P describes a perspective of *Commercial Pressure*:

> …one of my favorite quotes from one of the operators was “We pay our corporate attorney more in a month than your company makes all year” . And there is a concept of ‘look, were going to do what our CEO said a he will do on Twitter, and if you have a problem with it, either sue you or buy you off or what have you,’ and that is a much louder voice than even we have at our trade association. Let alone what I have, either with my company or individually. (Participant P, Reference 2 - 0.34% Coverage).
>
> So a lot of the stakeholders are – and again I’m not accusing anybody of anything, but this is business is business. So when you have it [the vertiport] built to support your needs and lobby and advocating and making press releases to make a certain cow [?] look a certain way – you want to make sure you are supported not necessarily your competition. And those are the challenges and things we have in play. (Reference 1 - 0.36% Coverage, Participant P Transcript).

An analysis of all five *Commercial Pressure* child codes from the participant transcripts revealed that *Corporate Failure is not an Option* was the highest coded expression, followed by *Political Pressures on Regulators* (regulatory bodies such as the FAA) and closely related *Manipulation and Pressures On Legislators* (individual elected officials and Congress). *Public Image Prioritization* and *Corporate Protectionism* were slightly less frequent child codes within this *Commercial Pressure*. All commercial pressure child codes were co-coded with varying amounts of *Sentiment*, and most child codes were expressed with very negative (-,-) or moderately negative (-) sentiment, which is supported by the prior analysis of affect of worry, concern, and fear. Interestingly, while participants expressed *Corporate Failure as Not an Option* as primarily very (-,-) negative and moderately (-) negative, some participants expressed moderately (+) positive and very (+,+) positive sentiments. The researcher noted this positive sentiment was co-coded in affect with excitement and the fun and novelty some participants are experiencing within their roles; Figure 47 captures this summary.

Figure 47

Commercial Pressure Child Codes and Sentiment All Stakeholders

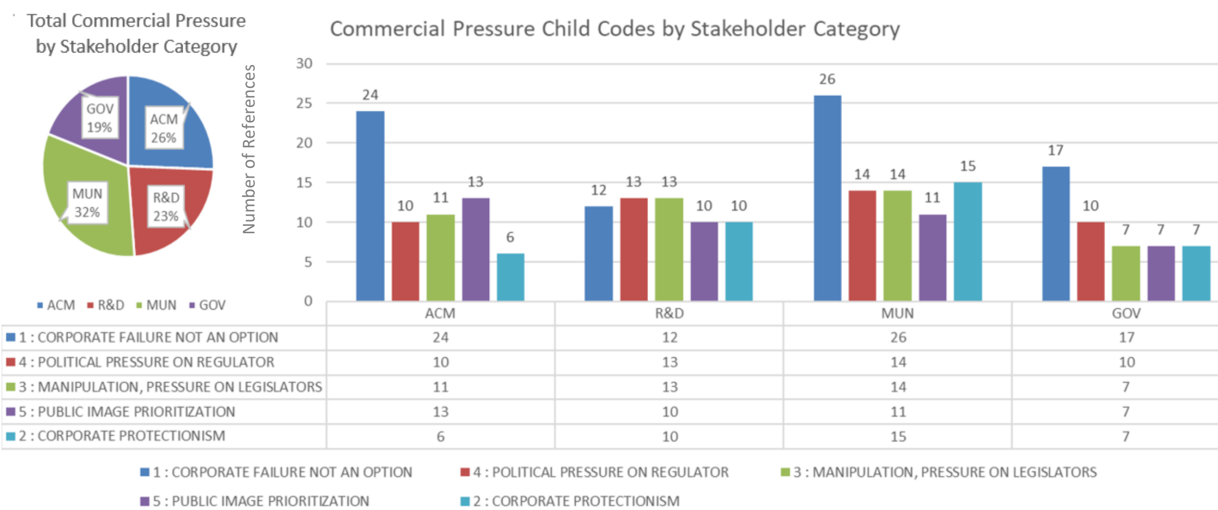


Note. The two graphs are shown together to illustrate the overlapping sentiment associated with the *Commercial Pressure* Child Codes.

When analyzing *Commercial Pressure* child codes by stakeholder category, the data revealed that stakeholders in the Municipality (MUN) category expressed significantly higher perceptions of *Corporate Failure Is Not An Option* than the other stakeholders and other *Commercial Pressure* child codes. Additionally, Stakeholders in the Municipality category indicated more frequent *Commercial Pressure* than the other stakeholder categories (32% of the coding frequency); in contrast, the Federal Government stakeholder category (GOV) measured 19% of the coding frequency for commercial pressure. The Aircraft and Component Manufacturers expressed slightly less *Corporate Failure Is Not An Option*; however, this was significantly more prominent than the other child codes for *Commercial Pressure* in their category. This increased contrast of the child codes within the ACM stakeholder group was interesting. It was unsurprising to the researcher that the Federal Government (GOV) stakeholder category coded as the least frequent for *Commercial Pressure*; however, it was interesting that *Corporate Failure Not an Option* was the most frequent child code for this group. Figure 48 presents a compound analysis of matrix coding for *Commercial Pressure* child codes by stakeholders.

Figure 48

Commercial Pressure Child Codes by Stakeholder Category



	ACM	R&D	MUN	GOV
1 : CORPORATE FAILURE NOT AN OPTION	24	12	26	17
4 : POLITICAL PRESSURE ON REGULATOR	10	13	14	10
3 : MANIPULATION, PRESSURE ON LEGISLATORS	11	13	14	7
5 : PUBLIC IMAGE PRIORITIZATION	13	10	11	7
2 : CORPORATE PROTECTIONISM	6	10	15	7

Summary of Findings Tertiary Data Analysis

Tertiary Analysis results provide enough insight into the data to present plausible answers to the remaining research questions: **RQ4**, **RQ5**, and **RQ 6**:

RQ4. How do UAM stakeholders' roles and responsibilities contribute to the safety efforts of the UAM ecosystem?

Each stakeholder interviewed expressed how their role individually contributed to building awareness and stimulating discussions, with all stakeholders expressing opinions that the importance of their role is to encourage more industry-wide partnerships and collaboration. 18/20 participants expressed experiencing fear, worry, and concern about the safety of the AAM vertiport industry. Although predominantly feeling negative, this appeared to be a motivator for their efforts in education and outreach. Included below are selected excerpts from participant transcripts from all stakeholder groups expressing how they perceive collaboration and cooperation:

> …yeah I think you know from my experience, the thing that we're dealing with the most within NASA's research projects and with involvement with the industry - is trying to gain a common ground where everybody can move forward in a methodical manner towards some future state - we can disagree on what that future state might look like, but we need agreement on what the near term steps are; Technology development regulatory change, you know and just where the research needs to go. (Participant A, Reference 1 - 0.47% Coverage)

> …our experience of - operation for us people who are involved in aviation so we rely on that – the other resources is that we maintain a good network of people who are aviation professionals, you know people who have developed 191 SMSs,

> [safety management systems] but they live with him [them] they work under them and you seek counsel – we've been fortunate in aviation in that we always have a very cooperative community of professional aviators. And to me that's an important resource. (Participant D, Reference 5 - 0.57% Coverage)

> I think part of the issue is that there is a lot that FAA cannot regulate fast enough and that's an impedance here in the states - I think also, there's a need for industry to collaborate and come up with what they call cooperative operating practices, COPS, and they used to be called something… CBPs.. I can't remember what that stood for… 'community-based practices' – so we switched from that nomenclature from CBPs to COPS. – it would be great if industry could come together and have some workshops to determine what they see happening for instance, the ones that are developing the UAM vehicles they could say 'this is how these work, and this is how this procedure is currently' and come up with some of the basic policies and procedures, for what would happen at UAM Vertiports. (Participant B**,** Reference 1 - 1.19% Coverage)

Additionally, participants expressed how, within their roles, they are motivated to provide education and outreach to other stakeholders and actively participate in industry programs run by NASA to learn more and help promote more understanding within the industry. Following are selected quotes from participant transcripts to illustrate these participant experiences:

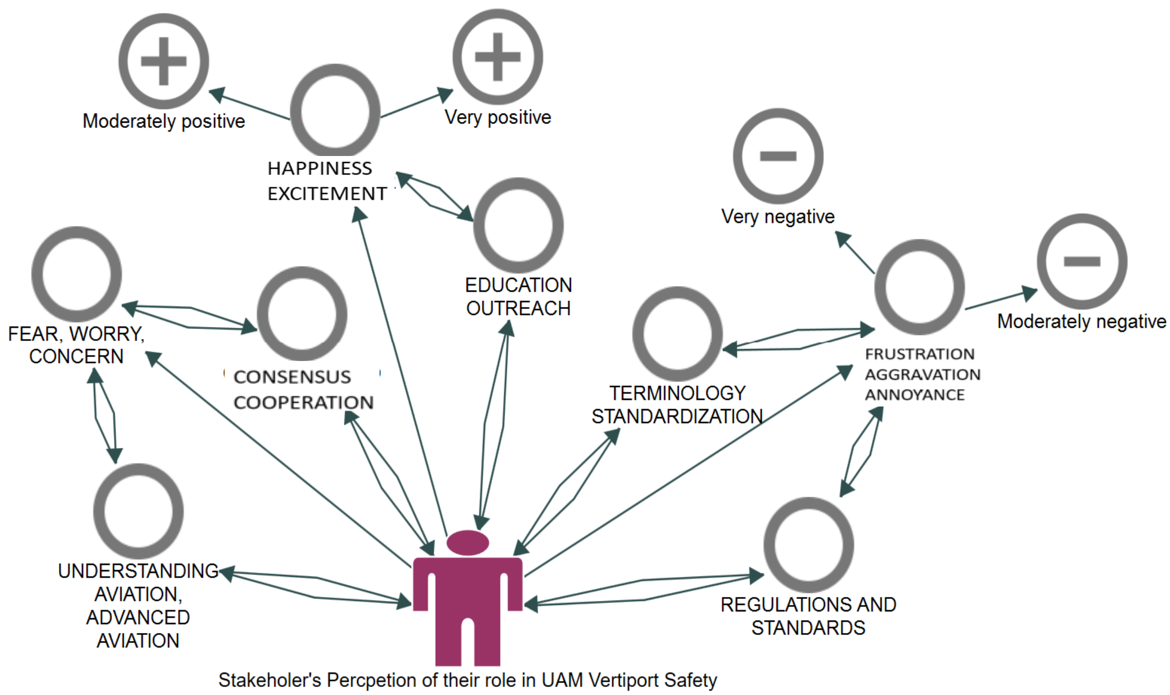
> I mean the number one piece of safety is that you have to educate right. If you know something is unsafe, and yet you allow people to do it, or people are

uneducated, they will continue to act unsafely if it seems to make sense at the time. – So yes, by creating road maps and having discussions and unknow, symposiums, and moderating panels, writing articles and things we are doing, we are getting that message out there so people understand it, as well as the lobbying and advocating work for legislative purposes. (Participant P, Reference 1 - 0.43% Coverage)

Education and Outreach were coded under the parent code of *Gaps and Lacks*, and *Consensus and Collaboration* were coded under the parent code of *Highest Priorities;* it appears that participants recognize the importance of their role as both an advocate and an educator for their particular stakeholder group to enable collaborative partnerships with selected industry partners to push through frustration and aggravation with the lack of published regulations and standards. In summary, the answer to **RQ4** is that the stakeholders feel their role as collaborators, educators, and advocates strongly contributes to the industry and, while frustrating and challenging, contributes to the advancement of the formal development of the industry. Figure 49 presents the summary of findings from the tertiary analysis through a conceptual model based on the tertiary data analysis in answering RQ4.

Figure 49

Conceptual Model: Stakeholder's Perception of Their Role and Experience in Advanced Air Mobility Vertiport Safety Systems



Answer to RQ5: How do these UAM stakeholders perceive their peers (stakeholders at other companies or organizations) experiencing problem-solving?

While Research Question RQ4 produced an overall uplifting and positive answer and conceptual model, the most complete answer to **RQ5** draws from the aggregate data that indicates industry stakeholder collaboration and consensus are working against an opposing force that decreases the willingness of trust, acceptance, and data sharing. While participants acknowledge each stakeholder category approaches their problem-solving challenges through their specific lenses, the data indicates stakeholders generally perceive many other stakeholders as not having as much of an understanding of UAM and vertiport safety as they should. Most stakeholders, including the Federal Government stakeholders, expressed frustration and aggravation at the Federal Aviation Administration and Congress for the slow pace at which the regulations are moving. The following are a few experts from the data indicating this coding (transcripts are not corrected for grammar):

> …whereas information I have is more about where is the FAA headed? What am - I - okay - what kind of dead bodies have I seen that you know kind of thing in FAA work and being a support contractor for them - so it's really more the scene underbelly of how the FAA works - how things *don't* get done - I've seen how tests and demonstrations end up being more political than hard science hard research. (Participant deidentified to avoid possible identification, Reference 1 - 0.55% Coverage)
>
> …there is two of them, and it really comes down to the ignorance of the status quo, and the reality of what happens below 500 feet. And I say that because there is a large portion of the new entrants into the market who believe that there is no aviation activity below 500 feet. (Participant P, Reference 1 - 0.42% Coverage)
>
> …I think it when I first heard that happen [changes and delays to regulation] it was frustrating and I just wanted to walk away from supporting FAA - to be honest I wanted to just feel like - all right I wanna just go and do something else, because it's kind of like sitting there watching paint dry. (Participant B, Reference 1 - 0.35% Coverage)

> …I do worry and get frustrated that sometimes we can take our historical perspective, you know we keep treating things like it's 1958 - and we constrain ourselves – we constrain ourselves in the ability to become safer – more efficient – more – to have a more democratized aviation, field of aviation - so it's a challenge of how much do you stay tied to the traditional where we feel safe and secure versus maybe we need to step out a little bit. (Participant D, Reference 1 - 0.86% Coverage)

Participants in all groups were more critical of Aircraft and Component Manufacturers in general (even participants in the ACM category), as having a lack of understanding of aviation and aircraft performance, with negative to very negative sentiments of fear, worry, and concern about the design of safety and risk management systems and even disgust at some of the perceived unrealistic depictions in the press and on social media about vertiports and urban air mobility. Following are transcripts from different participants illustrating the coded data:

> …So we have a lot of IP [intellectual property] that's developed over the last several years - without getting into the weeds I'll just tell you that - it's a lot more like just kind of 'gut checks' and - logical than probably our peers … - at least 'tout' about what that they do - you all these companies talk about 'big data sets' well, you know - "well I'm sorry but what big data sets exist that can show you how humans move"?! (Participant H, Reference 2 - 0.52% Coverage)
>
> …the data just doesn't' exist - and quite frankly - you know - people talk about Uber data, but - 95% of where those Ubers are dropping off and picking up

probably wouldn’t support a vertiport for a number of reasons. (Reference 3 - 0.30% Coverage)

…a lot of other companies in our industry are not or they are not openly honest about certain timelines and goals - and I think that discredits us and hurts our ability to get an industry up and running - so I call 2021 the year of the SPAC [special purpose acquisitions company] because a lot of the OEMs SPAC’ed, - and to SPAC spac you have to have a lot of nice marketing – and a lot of nice publicity – so there were a these fancy renderings of vehicles flying and landing and taking off from urban areas - I mean - I think I saw one with a vertiport in Central Park!! I mean just fundamentally *wrong* [emphasis added by participant] from the business model perspective - I mean you couldn’t underwrite that! (Reference 4 - 0.89% Coverage)

Further, there is a perception that some of these ACM stakeholder categories, along with a perceived lack of understanding of safety risks, favor the prioritization of satisfying the commercial pressures and their perceived public image as their highest priority. Additionally, stakeholders perceive other stakeholders as keeping their proprietary data secret and not sharing as much safety performance data as they should to advance the industry:

…but as things stand today, - the OEMs aren’t sharing enough with the regulatory bodies, the regulatory bodies aren’t sophisticated, savvy enough, or have the willingness to move quickly and bring themselves into the 21st century - FAA in particular. ATC is run by the unions, they each have their own culture and kind of do what they want so there's really no pressure to standardize anything. (Reference 6 - 0.50% Coverage)

…When I think you look at where helicopters operate in this space today, at structures we call heliports – there' certification requirements and under parts 27 and 29, specifically use certain terms that you don't find in part 23, - Hover – in ground effect power – out of ground effect power - and I think the most important one in part 27 and 29, stipulates that the aircraft must demonstrate controllability and maneuverability in all wind azimuths up to 17kts, that is not spoken to in 23 at all. (Reference 1 - 0.53% Coverage)

There are some that know qualifier snake, oil salesman I should buyer beware make sure you do your due diligence before you partner with anybody in the space. (Reference 2 - 0.16% Coverage)

These perceptions of other stakeholders contribute to an emergent theme of a lack of *within-industry trust* amongst the industry stakeholders. This lack of trust in other stakeholders is likely fueling efforts of *selective collaboration* while making competition between rival organizations more apparent. The following is an excerpt from a deidentified participant who expressed their perception and experience of the state of the AAM industry:

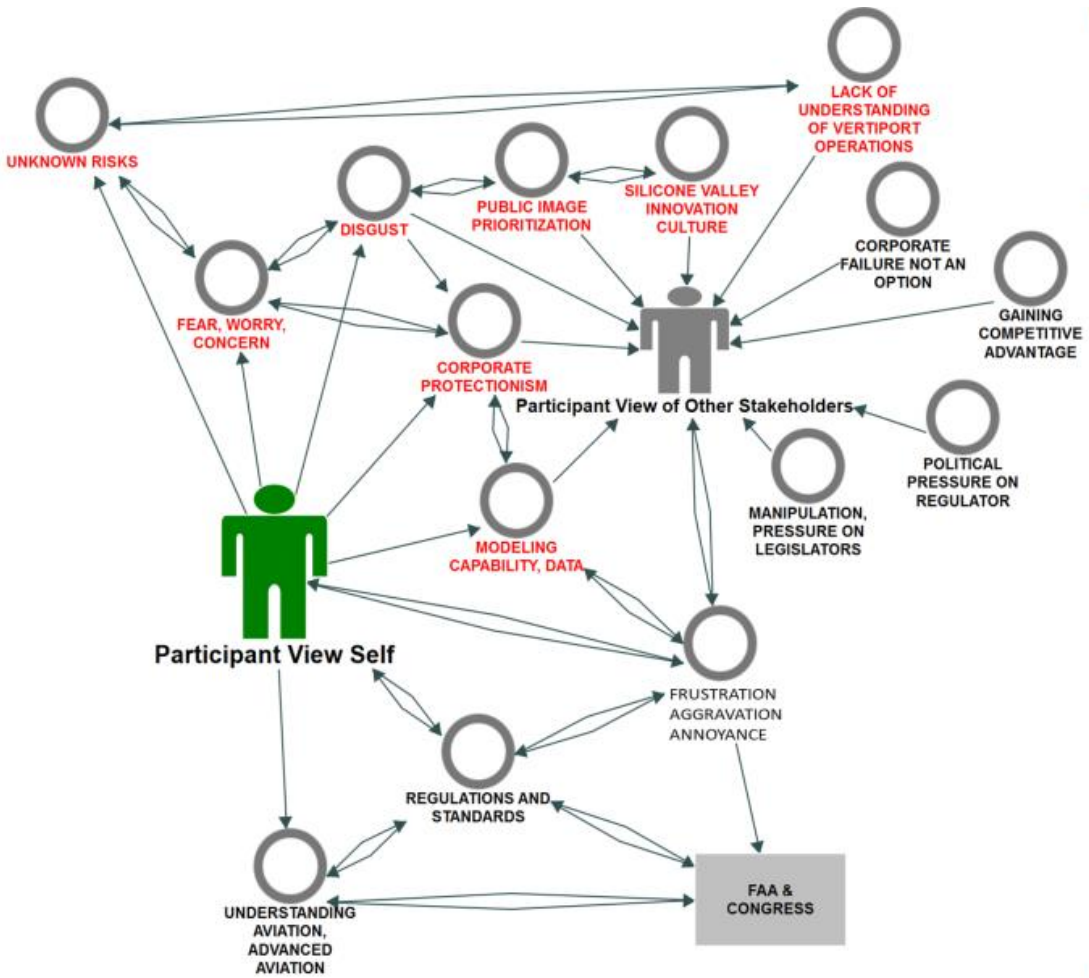
…- and look, there is a lot of hype - there's some dishonesty - that's going on - because when you have billions of dollars being invested the stakes are high, and people are willing to be less than honest about what the truth of the situation is - so my most difficult overall issue with the entire AAM endeavor now is that it feels very very lonely to have to be one of the people doing this - while others aren't willing to because they don't want to put themselves at risk - and I don't believe the industry will do well - unless we all start speaking up more [sighs seems disappointed]. (Participant Deidentified, Reference 4 - 0.71% Coverage)

So I would hope that somehow, the future operators of these aircraft this new technology come together and form an alliance coalition that can have a single voice, and that all who are part of that 181 compromise for the goodness of the entire industry being successful. And I will say that I doubt it will happen because everybody's already in such a competitive stance and looking to their own self-interest instead of the collective whole future of AAM. (Reference 5 - 0.58% Coverage)

How stakeholders perceive their peers and others within the UAM industry provided findings from the data suggesting significant barriers that oppose the education and collaboration data findings. The data indicates that industry trust may be an emergent theme. The data linkages aligning with *Within-Industry Trust* (WIT) are highlighted in red and presented in Figure 50.

Figure 50

Conceptual Model: Stakeholder's Perception of Self and Other Stakeholders in Advanced Air Mobility Vertiport Safety Systems



Note: Red labels indicate Dimensional Axial data coding revealing emergent *Within-Industry Trust* (WIT) barriers.

The Answer to RQ6: How likely are interactions with other UAM stakeholder peers likely to influence the participant's opinions on the design of safety processes, assumptions, and systems? The answer to this final question is overwhelmingly *highly likely* by all participants, who directly answered in the affirmative, as it was asked verbatim in the instrument. The clear and straightforward answer to **RQ6** reinforces the emergent theme of the need and willingness of the industry stakeholders to gain consensus and collaborate.

However, the motivation for participating in collaborative interactions and being influenced by others are many and include the following reasons from participant transcripts: (a) learning more about Advanced Aviation, (b) gathering insights from data not widely available, (c) building relationships with potential collaborative partnerships, (d) maintaining a competitive advantage, and (e) leveraging political and regulatory influence to hasten legislation and regulation. The following are selected transcript excerpts from different participants that illustrate this answer:

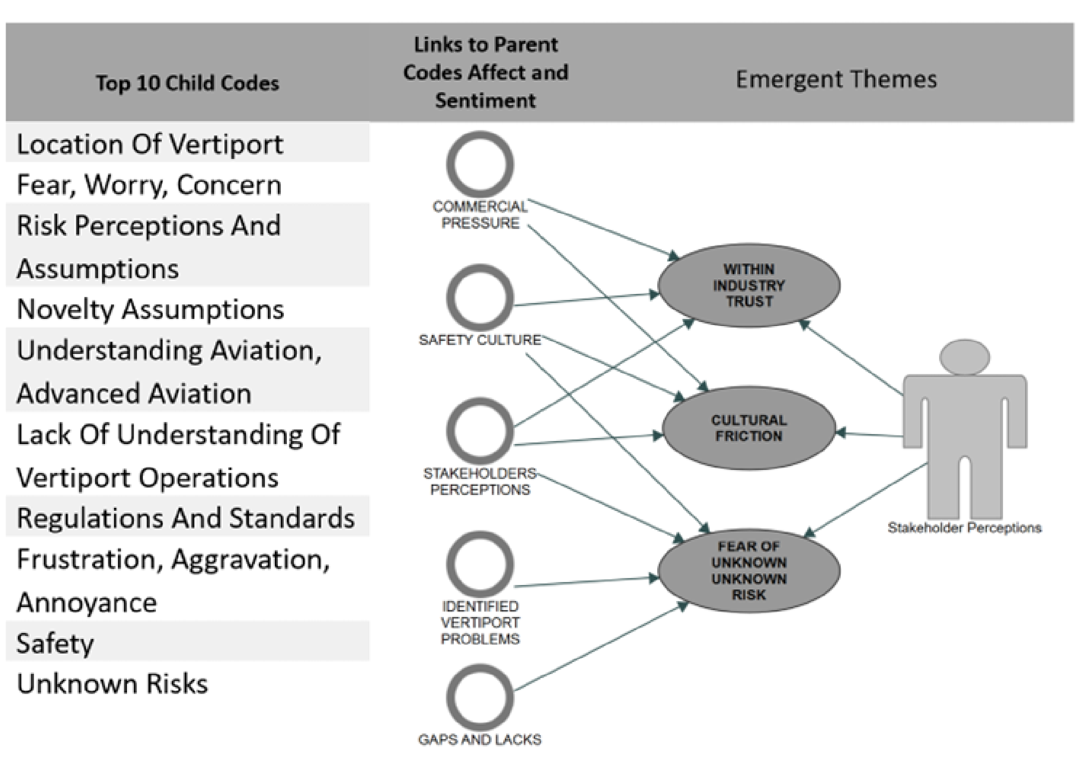
> …and that work gets promulgated through the working groups and the board and staff. And it’s just a really fantastically wholistic effort – so it’s not just our domestic organizations, but our partner organizations in Europe that we continue to work with as well. And that is really important, because all that together is really drives the most amount of operators and stakeholders involved – we pitch and present at our tradeshows, as well as other shows we go and have discussions and sit on panels and work through that. So it is a very wide – it isn’t really from the grass roots per say, because it isn’t really from the bottom up, but it is in fact 75 year vertical lift organization, and ah from the board down, and [redacted] get the message out and getting people involved. (Participant P, Reference 2 - 0.72% Coverage)
>
> …in terms of the how we tend to do the problem-solving on different levels so there are groups where we engage with the government, so there are venues - such as the advanced aviation, advisory committee, or the TSA working

> group on advance or mobility where private sector gets to talk with government and come together - to find solutions to enable their development of industry - there also trade associations and standards bodies that our company and others in the industry participate in - to come together and find common solutions to problems.
>
> - those environments are helpful - It's nice to have a structure in place for those types of conversations among industry players, - and also with - with government stakeholders, those groups can move a little bit slow [laugh] and be burdened by a lot of administrative, you know procedures, and so you know sometimes they can be frustrating [sigh laugh pause] - but those are you know good general Avenues for us to come together and - you know - talk about some of these issues and forward with some solutions. (Participant E, Reference 5 - 2.55% Coverage)

Finally, the results of the tertiary analysis provided enough information to answer all of the research questions and indicated relationships within the data to build a data model supporting possible emergent themes. Three emergent themes were identified from the aggregate data analysis: (a) Within-industry Trust barriers, (b) Cultural Friction, and (c) Fear of the Unknown Unknown Risk. Figure 51 presents the parent codes and their data links to the proposed emergent themes. The answer to Research Question RQ 1 is addressed in this figure with these three emergent themes.

Figure 51

Emergent Themes of Stakeholder Perceptions In Urban Air Mobility Vertiport Safety



Chapter Summary

This chapter followed a comprehensive yet methodical phased approach to data analysis, starting with the procedures and protocols to engage three independent coders who independently developed seven Parent Codes and 47 nested Child Codes, establishing the data's codebook. An initial review of 19 transcripts confirmed the data was rich with contextual descriptions and could support focused and axial coding for a thematic analysis from both the narrative and phenomenological perspectives. Additionally, there appeared to be consistent and considerable overlap through the data, including the transcript from the second pilot study, which was included with participant data, thus concluding the data collection process with 20 participant transcripts.

Data analysis began with a primary macro analysis establishing the frequency of codes and code hierarchy; from there, the secondary analysis focused on the impact of Affect– adding dimensionality to how the participants perceived their own experiences and how they felt about their work environments and the industry. In addition to Affect, the direction and magnitude of Sentiment were co-coded with many of the child codes to enable a deeper Tertiary Analysis that supported the analysis of axial and focused coding to discover the dimensional concepts around the participant's lived experiences, opinions, and perceptions. Finally, data models were used to illustrate plausible answers to the six research questions from the aggregated data analysis.

The next chapter will discuss these data models and revisit the primary research questions relating to the three emergent themes: (a) Within Industry Trust, (b) Cultural Friction, and (c) Fear of Unknown-Unknown Risk. The discussion will include possible explanations from the data of these themes and the potential to expand upon existing and perhaps new theories. Finally, Chapter V will propose areas for further research limitations and describe the potential applications of the findings.

Chapter V: Discussion, Conclusions, and Recommendations

This final chapter discusses the results detailed in Chapter IV and explains the answers to the research questions derived from the data. The richness of the data revealed code linkages, word frequencies, patterns, and relationships. These patterns were the foundation for building the conceptual models that emerged to construct a deeper understanding of the participant experiences, leading to the discovery of emergent themes and supporting possible new theories. This chapter also discusses the study’s limitations and the limitations of the findings and provides recommendations and opportunities for further research on practical industry initiatives that may be suggested for UAM vertiport stakeholders. The chapter ends with a concise conclusion and the researcher’s reflection on the body of research and recommendations for each stakeholder group.

Discussion

Unique Perspectives and Emergent Themes

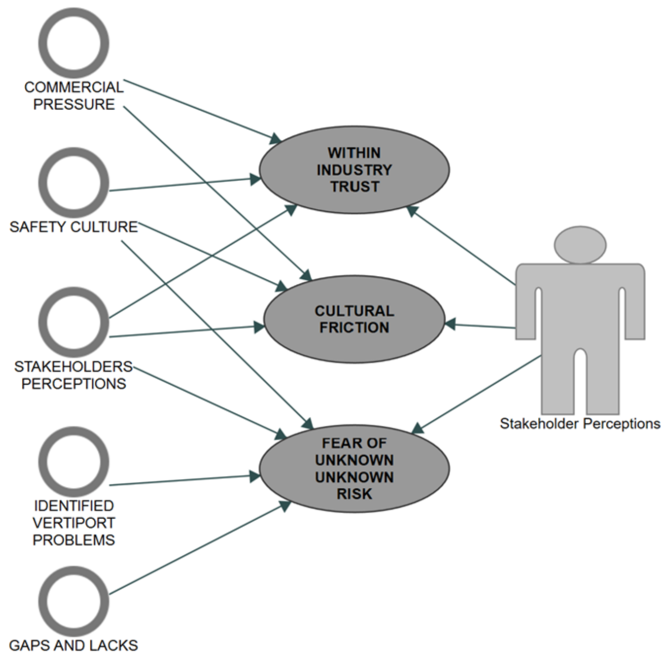
Chapter IV presented the aggregated results from unique stakeholder transcripts that contributed to the comprehensive data analysis phases and revealed code dimensionality, concepts, and ultimately emergent themes that emerged from the data. Further, this study used the plurality of phenomenological and narrative perspectives enhanced by creating *Affect* child codes to measure participant-expressed emotions, opinions, and experiences. Additionally, the sentiment's direction and magnitude were coded to support the depth of the phenomenological data by measuring and adding context to the participants’ lived experiences. The phenomenological results provided a valuable, more profound understanding of the context of the narrative; therefore, combining this study’s narrative and phenomenological perspectives was a sound qualitative analysis strategy that can reduce complicated things like human emotions and unique perspectives into parts for analysis and understanding (Miles & Huberman, 1994), which is the basis for theorizing (Corbin & Strauss, 2008).

Although participants expressed their unique perspectives from their personal and professional lenses, they shared a commonality with how they are experiencing the emerging advanced aviation industry and their challenges with establishing safe UAM vertiport operations. Each participant also provided rich and thick context to the lines of inquiry in the research instrument; the purpose and scope of this study were to determine emergent themes from the population as a whole and to understand how the stakeholders are as a collective community experiencing these problem-solving efforts in a highly conceptual, and relatively immature emergent industry. The unique differences between the participants from each category are also highly contextual and may provide an opportunity for further analysis, which may be significant in helping the stakeholder community collaborate on solutions.

Three emergent themes were derived from the data analysis: (a) *Within-Industry Trust*, (b) *Cultural Friction*, and (c) *Fear of Unknown-Unknown risk*. As Figure 52 illustrates, participants share these experiences, even though their specific areas of concern, opinions, and decisions about others and the industry may vary according to their frame of reference.

Figure 52

The Three Emergent Themes of Stakeholder Perceptions In Urban Air Mobility Vertiport Safety



Three Emergent Themes

Within-Industry Trust (WIT). Previous studies have indicated that trust is critical in generating public acceptance of autonomous vehicles, which includes urban air mobility as a form of transport (Al Haddad et al., 2020; Jenkins et al., 2018; Zang et al., 2019). Additionally, trust is an influential human factor that has been shown to influence passengers' willingness to fly (WTF) electric vertical take-off and landing aircraft in the advanced air mobility ecosystem (Ragbir et al., 2020; Rice et al., 2019; Winter et al., 2020). While abundant research focuses on trust and willingness to fly from the traveling public's perspective, few studies have examined the effects and levels of trust among the industry stakeholders who are designing and building the systems; this is an interesting perspective as industry stakeholders are the ones at the forefront of the industry and are responsible for developing and implementing the complex elements of the AAM ecosystem. Therefore, this study contributes new information indicating that UAM industry stakeholders are as relevant as the traveling public regarding trust across many complex elements that will make up the Advanced Air Mobility Ecosystem. Furthermore, industry stakeholders also need to have a level of trust in the other stakeholders who share the responsibility for the design, development, and implementation of these elements.

Urban Air Mobility stakeholders' perceptions of trust expand beyond the physical hardware and software of the eVTOL aircraft; trust must be perceived through all the connected systems involving other human actors, especially as the technology is assumed to become autonomous and automated. System-wide trust is a term emerging in literature as it relates to Safety Management Systems (SMS) for advanced air mobility; in fact, Ellis et al. (2021) describe a new generation of SMS focusing on total systems integration (ICAO, 2018b). There is a missing element to the body of work relating to Urban Air Mobility SMS, and that is the critical element of trust in the operators behind the autonomy. The results from this study indicate that system-wide trust inevitably extends to trusting the humans behind the technical systems and even extends beyond the system designers to lawmakers, regulatory bodies, corporate executives, and the expectations of the investors and communities.

Enabling the integration of the complex Advanced Air Mobility ecosystem includes algorithmic software design, cyber security capability, machine learning and artificial intelligence, and various levels of automation; these are all conceived, developed, and enabled by human operators and then require trust to be used by other humans. These other humans include those who are closer to the operation, including air traffic controllers, pilots, remote pilots, vertiport staff, maintenance personnel, airspace, and other system designers, all of whom directly influence the safety and reliability of the whole ecosystem (Chancey & Politowicz, 2020; Parasuraman, Sheridan, & Wickens, 2000). Therefore, humans need trust in these interconnected human and machine relationships to operate safely and efficiently (Hancock et al., 2011; Lee & See, 2004; Schaefer et al., 2016).

Human relationships are complex and multi-dimensional; they include personal and professional interactions that stir emotions, direct and support the formation of behavior and opinions, and result in decisions. While there is abundant research on public acceptance, WTF, and trust in UAM, few studies focus on the Within-Industry Trust (WIT) of the UAM industry. In this study, the codes and subcodes of *Within-Industry Trust* emerged as challenges or barriers shared amongst all stakeholders (see Figure 50); of course, levels of trust can vary and may be perceived differently through participants' unique lenses. The results from this data were fascinating in that most participants expressed fear, concern, and even disgust that other stakeholders demonstrated corporate protectionism, as they perceived others are not sharing their data and operational information that could help the industry while at the same time doubting if those [other stakeholders] even possess any of the data they claim to have, and have enough of an understanding of the UAM industry to contribute something worthwhile. The data showed that this perception of mistrust was intensified by stakeholders expressing *Disgust* at other stakeholders who are producing unrealistic renderings and videos, making false or fanciful claims, and promoting these on social media and other industry news platforms. While many participants expressed disgust, it was usually [co-coded] within the context of genuine fear, worry, and concern about known risks and the acknowledgment of unknown risks expressed by the participants. Cumulatively, these complex perceptions seem to work together to exacerbate the challenges of forming an acceptable level of *Within-Industry Trust*.

Unrealistic Messaging. Participants often described the unrealistic messaging and renderings produced by some stakeholders and seemed to acknowledge that this compounds the challenges they are all facing as an industry and supports the perception that these [others] stakeholders lack understanding of Advanced Air Mobility and, therefore, pose a significant risk to the community's perception of UAM and UAM vertiports. Suppose the communities believe the messaging and images some stakeholders are promoting. In that case, the public perception will create false expectations and increase the commercial pressure to deliver, posing a risk to safe operations. These unrealistic expectations and possible risks ultimately threaten the industry's success as a whole. The data indicated that the perception that other stakeholders don't have enough understanding of Advanced Aviation was the most prominent of child codes under the gaps and lacks parent code, and therefore a significant barrier to establishing *Within-Industry Trust*.

Commercial Pressure. Commercial pressure emerged as a significant barrier to trust; commercial pressure has been widely researched and is recognized as a causal factor in many aviation accidents, stemming from financial priorities that compromise safety. Aviation organizations and their executives are usually under pressure to maintain schedules, meet profit targets, lower costs, and gain and maintain market demands; these are often in conflict with safety priorities and risk mitigation initiatives. Research by Wiegmann and Shappell (2001), in their human factors analysis of commercial aviation accidents, highlights how organizational factors, including commercial pressure, can influence decision-making and lead to errors. Moreover, a study by Helmreich and Merritt (1998) emphasizes the impact of these commercial pressures on pilot performance, aircraft maintenance, and safety culture within airlines. There has been no published literature examining the effect of commercial pressure in the emerging UAM industry; however, the results of this study show that commercial pressure is likely to be a significant factor in future UAM accidents and that it may be more intense and widespread compared to that of traditional aviation.

Trust in the Regulator. Dynamic factors influence public and industry trust in the regulators and the regulations they promulgate, especially in areas requiring legislation for innovation, technology, and sustainable energy (Mitchell & Woodman, 2010). Trust is a critical factor; if regulators are perceived to be acting in a timely, fair, and proactive manner, people will trust the motives of that authority and will tend to embrace their decisions (Larzelere & Huston, 1980; Mitchell & Woodman, 2010; Pautz, 2009; Rice et al., 2015).

Interestingly, the data in this body of research showed that participants (even those who worked within the government) were frustrated, aggravated, and annoyed with the FAA and the lawmakers, including Congress as a whole. Participants generally shared the perception that Congress and the FAA don’t understand how to regulate the Advanced Air Mobility and emerging Vertiport industries, and (b) local government officials, lawmakers, and the FAA are being overtly pressured by [other] industry stakeholders who “lawyer up” to get their particular policy preferences into legislation for their own stakeholder’s commercial benefit rather than the industry's greater good. In summary, the data revealed that stakeholders' perceptions and the sub-codes of

Commercial Pressure were among the most prominent in contributing to barriers to within-industry trust, and that extended to a lack of trust and confidence in the regulator and government.

Cultural Friction.

Background. The term *culture* may be interpreted through different perspectives; however, as it relates to the perceptions in this study, the participants seem to understand and interpret its conventional intent as it relates to aviation safety and human factors. Previous work identifies three distinct cultural aspects identified as shaping behaviors, attitudes, and decision-making, which ultimately affect safe operations (Helmreich, 1999; Helmerich & Merritt, 2019). The most apparent cultural perception is *National Culture*, referring to the collective norms, traditions, and perspectives of those from a country or region (for example, traditional Japanese culture compared to that of the United States in the same era). As it relates to the participants in this study, the perceptions of culture are delimitated to UAM in the United States of America. Secondly, there is the *Professional Culture*, which refers to norms, practices, and behaviors associated with being a member of a particular profession, for example, a Pilot, a Lawyer, or a Chief Executive Officer (House et al., 2013).

The third cultural perspective is the *Organizational Culture*, which is almost like a micro-culture within the professional and national culture that strongly influences the organization's relationships and functions (for example, the safety culture in an offshore oil and gas company compared to the safety culture in an emergent uncrewed aviation company) (Lamb 2019; Lamb et al., 2021). Through these perspectives, cultural influences must be considered a critical factor in aviation leadership behavior and decision-making (Global Leadership and Organizational Behavior Effectiveness [GLOBE], (n.d.); Helmreich, 1999; Helmreich & Merritt., 2019; House et al., 2014).

Culture in Leadership. Organizational leadership is a pivotal factor in generating safety culture; the Global Leadership and Organizational Behavior Effectiveness (GLOBE) study is a comprehensive, multinational research initiative investigating cultural influences on organizational leadership across various national cultures. The GLOBE findings found nine cultural dimensions that influence leadership: Power Distance, Uncertainty Avoidance, Collectivism I (in-group collectivism), Collectivism II (institutional collectivism), Gender Egalitarianism, Assertiveness, Future Orientation, Performance Orientation, and Humane Orientation. The nine dimensions provide an understanding of how cultural values and norms influence leadership decisions and behaviors, such as the preference for those in leadership positions, the tolerance for risk and uncertainty, how groups collaborate, gender equality [sexism], tolerance for assertiveness, time orientation, performance focus, and concern for societal welfare (House et al., 2013).

Divergence of Culture in Urban Air Mobility**.** The nine dimensions outlined in the GLOBE study can be observed in the data analyzed from this study, which underscores that organizations, particularly their leadership, must fully understand cultural influences on their operations to succeed. This study also provides additional results to support the idea that organizational culture is not only a micro-culture within a company but can potentially impact the broader industry culture.

Regarding the emerging advanced aviation industry, the results of this study also suggest that the aviation industry appears to be diverging into distinct sectors or groups: traditional, advanced, and small uncrewed. This divergence has positive and negative aspects: the positive aspect of innovation while conversely being driven by many stakeholders with minimal aviation expertise. The minimal aviation experience of the new entrants into the aviation industry is a source of fear and worry concerning potential safety risks. The data indicates that many stakeholders perceived individuals from two different and distinct *cultures* within the emergent AAM industry: (a) those who come from a background of traditional aviation and (b) the *new entrants* who come from a technology, innovation, or business development background [often referred to as the Silicon Valley Culture]. The stakeholders with a traditional aviation background often describe their culture as one that has evolved since 1903, representing over 100 years of lessons learned from accidents, often described as paid for *in blood* by those who lost their lives. In contrast, the Silicon Valley culture did not develop due to aviation mishaps; it has an innovative *fail fast* get-to-market energy, described as dynamic and creative, arguably a desirable and critical factor in technological advancement and being globally competitive.

One of the vital findings from this body of work concludes that if the future of aviation is to advance safely and quickly, these very different cultures need to merge into a new type of unified industry culture, one that takes the agility and creativity of innovation yet includes the mechanisms to support the next generation of operational safety. Automation and other technology developments impact aviation safety performance; they can germinate from a variety of sources, including opinions and decisions made at the management level, financial constraints, training inadequacies, lack of resources, and logistical issues, and usually manifest at the front line of the operation in the form of mishaps, accidents, near misses or other financial loss (Flin et al., 2008; Orlady & Orlady, 1999; Reason, 1990).

The International Civil Aviation Organization recognizes the impact of technological developments on aviation safety, which includes the tightly bound relationship between safety culture and safety management systems). It has developed its guidance materials and standards from 100 years of aviation and lessons learned. The latest version of the ICAO SMS Manual (4^{th} edition, 2013) illustrates the evolution of aviation safety culture from the early days of recognition and study of human factors to organizational factors to the emergence of a new era of culture that must include the confluence of technology, autonomy, and a total systems approach. This study provides results that support the ICAO philosophy for an emergent safety culture and may provide insight into a foundation for enabling strategies for this new total systems cultural era.

As discussed in the previous section, the first emergent theme of this study was *Within-Industry Trust*, which is an essential foundation for generating a new innovative safety culture for advanced aviation; the spirit of collaboration and willingness to share safety data for the greater aviation good is not a rare or isolated activity in safety-critical industries. Lessons learned in aviation have been applied in other sectors, such as oil and gas, medicine, and nuclear power. The data from this study indicates that despite the friction between the traditional and the innovation cultures, the seeds of a new generation of innovative safety culture are present but need enabling strategies to grow and flourish.

Fear of Unknown-Unknown Risk.

***Fear and Willingness to Fly*.** Fear is a strong human emotion that has been shown to influence passengers' willingness to fly and accept new advanced air mobility technology (Rice et al., 2019; Tepylo et al., 2023). Public perception and acceptance of Urban Air Mobility Vertiport operations and flying on the aircraft are recognized as critical enablers for the industry and are at the forefront of most industry stakeholders' minds. However, the data indicates that the stakeholders in this emergent industry express high levels of fear, worry, and concern about the yet *unknown* risk factors likely to cause mishaps. All participants in this study expressed their awareness that AAM and Vertiports will likely follow the path of traditional aviation, that is, learning from mistakes and inevitable accidents and incidents. It is a daunting proposition that the risk factors of future UAM vertiport accidents lie dormant in the systems being designed today, their potential to cause harm remaining unknown until failures occur.

***Lack of Tools and Guidance*.** The results presented in Chapter IV indicated shared experiences of moderately negative to very negative feelings of fear, worry, and concern, often while also feeling frustrated and aggravated about the industry's lack and gaps, including the lack of collective safety data, lack of modeling, and lack of standards and guidance. Participants expressed they are aware of the existence of unknown risk factors, some related to aircraft performance, and other fears related to how they will integrate the UAM operations at vertiports into the UAM ecosystem. Additionally, the stakeholders perceived that these risk factors are not yet known or identified by the regulators or standards bodies. This lack of regulatory guidance and standards, while primarily causing frustration, also appears to be a significant contributing factor to the fear, worry, and concern about the unknown.

***Risk Perspectives and Automation Assumptions*.** Stakeholders expressed differences in their perceptions of specific elements of vertiport safety; for example, the researcher identified that participants from the Research and Development and the Federal Government stakeholder categories have more technical concerns about the location of the vertiport as it relates to aircraft performance (such as rotor vortices, disk loading, and transitional flight challenges) yet, local government and municipality stakeholders are worried about the locations of the vertiport with a community-based focus (obstacles, fire, and first responder capability). However, the commonality between the stakeholder groups supported the emergence of the *Fear of* the *Unknown-Unknown Risk* theme. The differences between the industry stakeholders were reflected in the differences in their perception of the types of risk factors likely facing UAM vertiport operations, and therefore, one of the recommendations from this study is to be aware of the importance of a wide variety of industry stakeholder input for the design of all aspects of the advanced air mobility ecosystem, and in particular, operations at UAM vertiports.

Additionally, the data revealed that the fear of unknown-unknown risks manifests from stakeholders' perceptions of novelty assumptions related to automation and autonomy. The data showed that assumptions on the levels of autonomy are driving investor and corporate perceptions of high volumes of departures and arrivals at UAM vertiports despite the lack of real-time data modeling for these operations. These automation assumptions also seem to contribute to the perceived lack of understanding (by others) of vertiport operations, aviation, and advanced aviation. These differing risk perspectives and assumptions of autonomy appear to be responsible for intensifying this fear in the stakeholders. Compounding the stakeholders’ fear is that there are considerable gaps and a lack of information, standards, data, models, and other resources that they could use to discover and mitigate previously unknown risks.

Each stakeholder has a unique perspective and has the potential to contribute to unique aspects of safety data to help the industry as a whole; however, the lack of trust and cultural barriers are diminishing the willingness of stakeholders to be open to sharing data and lessons learned. Much like a giant jigsaw puzzle, if each stakeholder was motivated to share safety data from their experiences, it is likely that many currently unknown risks could be discovered, and the building blocks of new mitigation strategies could be developed. Knowledge is a powerful antidote to overcoming fear; once stakeholders can identify and understand risk factors, they can build precautions into their safety systems, even if the risk factor cannot be fully eliminated or treated. Additionally, when industry stakeholders unite to solve problems associated with risk factors, it can build within-industry trust and establish the foundations for a much-needed new emergent aviation safety culture.

Conclusions and Recommendations

Results from this study point to three emergent themes that impede the safe, efficient development and implementation of urban air mobility vertiports and flight routes. These three themes, *Within-Industry Trust, Cultural Friction,* and *Fear Of Unknown-Unknown Risks*, are themes that, once understood, may be countered or even used as enablers to help the industry succeed faster and more safely while delivering a return on investment for its investors. As the data indicates, the three themes are closely related, and implementing proactive initiatives in one theme area will likely have a positive and significant effect in the other theme areas. Each theme shares elements of human emotion and sentiment; for example, if regulators were to develop an initiative for open generic UAM Vertiport data sharing, it is likely levels of within-industry trust among the stakeholders would (to an extent) increase. Therefore, two high-level recommendations are suggested here and discussed further in practical contributions. The two high-level recommendations are open data-sharing initiatives to help generate a new evolution of safety culture in which data sharing and innovation are supported by traditional safety and risk disciplines and a code of conduct for responsible UAM community promotion.

Generating an Innovation Safety Culture

Within-Industry Trust may be cultivated by independent data sharing and transparency initiatives, very similar to existing programs currently used in aviation and other safety-critical industries, such as the FAA InfoShare conferences and other collective industry-wide safety data sharing mechanisms, such as those used by the industry non-profit group HeliOffshore. HeliOffshore is the global, safety-focused association for the offshore helicopter industry, with its mission to lead a collective safety conversation, identify the right priorities supported by the right resources, and deliver the right actions to transform frontline safety performance (Helioffshore.org).

If generic UAM Vertiport data is freely available, then the industry will be motivated to generate a data-sharing safety culture. Safety culture is a complex and intricate phenomenon affecting UAM vertiport stakeholders, specifically the perceived friction between traditional aviation and Silicon Valley innovation culture. While some stakeholders describe this friction as a positive element that disrupts many traditional non-agile approaches to innovation, it is also a profound source of worry and concern for many decision-makers in the industry who have seen negative consequences of being too fast to market or allowing commercial pressures to justify system design and operational decisions. An example of the latter is the Boeing 737 Max accidents in 2018 and 2019, in which the National Transport Safety Agency found causal factors, including commercial pressures and autonomy assumptions.

UAM Industry Code of Conduct

One pivotal data analysis conclusion indicates that some stakeholders promote the emerging UAM industry as having performance and attributes not justified by publicly available data. In an era of highly realistic computer animation and AI technology, these images and promotions are proving harmful in establishing unrealistic expectations by investors and the communities UAM vertiports promises to serve. The harm of unrealistic expectations often manifests in the industry as commercial pressure and mistrust, as the data from this study shows, a mistrust among the industry stakeholders.

Closely related to an open data-sharing initiative, the regulators, lawmakers, and government bodies should support establishing a code of conduct; it may enable the emergent aviation industry to help itself from within by outlining guidelines and standards for UAM messaging that must be supported by data, even if that data is based on computer-based systems engineering and justifiable simulations. Although the regulators generally set the pace of implementation, empowering the industry from within will involve mechanisms for a new *Innovative Safety Culture* while at the same time cultivating trust and confidence in the government's ability to legislate and develop standards and guidance.

As previously discussed, establishing a UAM code of conduct, strategies, and initiatives that support open data-sharing and transparent operational safety practices will likely diffuse some within-industry trust issues, fostering a more relaxed and collaborative environment. Additionally, more collaboration will help support increased communication and knowledge sharing about risks and help to discover potentially unknown risk factors. A UAM code of conduct will also assist the industry in managing investor expectations, provide a platform to build realistic expectations, and thereby remove an element of commercial pressure that is a known causal factor in aviation accidents. Finally, establishing a UAM code of conduct may also assist the regulator in promulgating timely and implementable regulatory and standards roadmaps.

In summary, the two recommendations for developing an *Open Data Sharing Initiative* and establishing a *UAM Industry Code Of Conduct* may create a foundation for responsible and sustainable growth in the UAM industry. Open data sharing and a code of conduct promote an ecosystem where information is accessible, standards are clear, and stakeholders are accountable, fostering an environment conducive to innovation, safety, and public trust--ultimately a key enabler for the evolution of a UAM Innovative Safety Culture. Additionally, these initiatives can help build a positive reputation for the UAM industry in the United States, attracting more investment and collaboration from within the global UAM industry.

Theoretical Contributions

The primary theoretical contribution of this study is the discovery of the emergent themes of UAM vertiport stakeholder perspectives discovered in the data. The research undertaken in this effort has contributed a robust, repeatable qualitative design using the plurality of phenomenological and narrative perspectives while using Affect and Sentiment as a tool to build context and understanding of codes and themes, which may be used to develop quantitative variables in further research. The design and research method had not yet been applied to UAM vertiport stakeholders and their challenges. This research is the first of its kind and fills a gap in the literature on building comprehensive and inclusive safety management systems at UAM vertiports. It also contributes to the broader body of knowledge regarding aviation safety and human factors in the UAM industry.

Further, this research contributes new knowledge to the understanding and literature relating to human performance and System-Wide Trust (SWT) strategies investigated by Rice and Geels (2010), which supported the expanded theory of System-

Wide Acceptance Trust (SWAT) and parallels of connections between Gestalt psychology's law of similarity and system-wide trust in complex and autonomous transport (Bean et al., 2011; Blair et al., 2012; Deaton et al., 2016; Rice & Geels., 2010; Keller & Rice., 2009, 2010; Rice et al., 2016; Walliser et al., 2016). The link between human emotions, particularly those attached to negative sentiment, has strongly influenced system-wide trust across complex environments, directly influencing human performance within the system. The results of this study offer additional support to the studies by Bean et al. (2011) and Keller and Rice (2009), suggesting that trust cannot be directly measured but is inferred from the behavior and performance of the participant, further supporting the connection to Gestalt psychology. This study used the highly contextual data in qualitative transcripts to gain insights into perceptions and opinions that influence behavior, the bedrock of Gestalt psychology (Bean et al., 2011; Rock & Palmer, 1990). As this body of work is the first of its kind to investigate the opinions and perceptions of industry stakeholders, revealing significant results in the area of trust within the UAM community, it extends the literature on trust by adding the perspective of *Within-Industry Trust* from the perspective of the decision-makers at the forefront of system development. Therefore, the concept of *Within-Industry Trust* seems worthy of further investigation within other safety-critical industries emerging in the high-technology era, such as electric self-driving cars and the commercial space industry.

The data generated from this body of work identifies and discusses additional theoretical contributions to the knowledge and application of aviation safety culture philosophy and the factors that both support and potentially degrade a safety culture. The results indicate that the current understanding of aviation safety culture needs to evolve to include the next generation of aviation entrants, emphasizing the potential impact of dynamic, fast-paced technology disruption, novelty assumptions, and autonomy on human expectations and relationships within an aviation operation.

The results of this study further contribute to the theoretical foundations and understanding regarding the impact *affect* (emotions) have on the perspectives, opinions, and decisions of those in safety-critical industries, such as aviation. The results of this study show how *affect* can be influential in system design and how preferences manifest in business strategies, partnerships, messaging, and marketing, as well as impact safety culture and industry trust.

Finally, the many child codes generated in this study provide the opportunity for further investigation. They may offer a new theoretical foundation of the critical ingredients required to build the next generation of aviation safety management systems. These child codes may be transformed into quantitative variables that could be used in future studies, including their role in mediation and moderating *Within-Industry Trust.*

Practical Contributions

Practical contributions from the results of this study may have broad implications for the Advanced Air Mobility industry as a whole and assist individual stakeholders within their specific areas of operation. Firstly, this study's most prominent contribution is identifying the three emergent themes. These emergent themes are accurately captured and measured in the data, representing human perceptions, reflections, and opinions of the stakeholders at the forefront of leading and contributing to the UAM vertiport industry. From the practical standpoint, the acknowledgment of three themes demonstrates the need to establish an innovative safety culture for advanced aviation, which supports the evolution of innovation commensurate with the development of safety.

Secondly, the findings from this study highlight the need for initiatives to support open data sharing, enhance within-industry trust, alleviate fear and worry, and develop a more collaborative spirit to build innovative safety systems. Previous studies that employed similar qualitative methods have used their data to implement practical solutions to societal problems associated with racism, academic and school student engagement challenges, and issues with both civil and political engagement (Rappa & Jamil, 2020).

Therefore, the practical contributions of this study are relevant to advanced aviation stakeholders, especially policymakers, in solving the issues of *Within-Industry Trust* challenges, developing a new innovative safety culture, and supporting data and operational safety sharing to help discover unknown risks. There may be several practical implications, which are discussed in the following paragraphs.

Educating Industry Stakeholders. The findings from this study can provide valuable insights to other UAM industry stakeholders, including companies that support the stakeholders, government research agencies, standards bodies, policymakers, communities, and Congress. Understanding the cultural friction and lack of trust within the industry allows stakeholders to address these issues proactively, fostering better collaboration and cooperation. Additionally, acknowledgment and understanding that cultural friction and lack of within-industry trust is a barrier to the safe and efficient implementation of UAM Vertiports may help stakeholders identify areas for improvement in messaging to the general public, creating more realistic expectations for public perception and possibly alleviating commercial pressure from investors.

Supporting Trust in Policy and Regulation. The identified themes and supporting data from this study may inform regulators about the importance of transparency and realistic expectations for developing policies and regulations in the AAM industry. Additionally, policymakers can use the insights from this data to design regulations that address cultural differences and promote trust-building measures while also setting expectations and messaging for the industry to have faith in the law-making process and transparency of realistic and equitable certification processes.

Enhancing Communication Strategies. The data from this study shows the possible and likely causes of cultural friction between traditional aviation and emerging aviation, and this data points to the potential sources of the perceived lack of within-industry trust; therefore, enhancing communication strategies and more realistic and strategic messaging may be used to guide communication policy within the industry. The industry may consider a type of *communication code of conduct* so that the industry as a whole may develop communication plans that acknowledge and mitigate these issues, fostering a more transparent and cooperative environment while setting realistic expectations and enhanced trust.

New Training and Development Programs. Stakeholder companies in the UAM industry may use the study's findings to tailor employee training and development programs for their various vertical departments, such as messaging for their marketing departments and the importance of developing the safety culture aspects for their flight and engineering departments. Training programs that address these identified safety culture differences proactively while actively identifying and promoting areas where they can share data will build trust and enhance overall collaboration and productivity among individual stakeholders and the industry.

Educational institutions such as technical colleges or universities may use the findings in this study to develop and offer new training programs related to the AAM industry, including extending current programs on aviation safety and safety culture to include the evolution of safety culture in the emerging UAM and vertiport industry. Additionally, the FAA and other regulatory bodies may use the study's findings to adapt existing curricula to accommodate and educate industry stakeholders on these new emergent themes and how to address the industry's current challenges. Integrating content that addresses the different stakeholder perceptions and cultural differences may enhance industry-wide trust-building and better prepare future professionals for the challenges in the UAM industry.

New Risk Management Strategies. The fear of unknown risks is a critical theme that emerged from this data; however, acknowledging this theme creates awareness that more attention needs to be focused on initiatives to support open data sharing that can inform new risk management strategies. Stakeholders who participate in open data-sharing activities or initiatives may benefit from identifying and assessing potential risks from an additional or novel perspective and do so more comprehensively than if they were to try to solve these challenges alone. Collective industry-wide data sharing and analysis may provide a more significant opportunity for hazard identification activities, with more minds to solve problems and work on solutions to develop robust risk mitigation plans.

Guiding Future Research. The identified themes can serve as a foundation for future research in the AAM industry. Researchers may explore each theme in more depth, investigating specific factors contributing to cultural friction, trust issues, and the fear of unknown risks, thereby expanding the body of knowledge in the field. The codes and sub-codes that contributed to each emergent theme may also be examined in greater depth; for example, further investigation of the mediating or moderating effects of commercial pressure may directly influence operational safety.

Accelerating Community Adoption. UAM stakeholders may use the findings in this study related to the stakeholders' perceptions to develop more realistic strategies for strengthening public perception and trust in UAM vertiports and UAM operations. Clear communication about safety measures and risk mitigation efforts rather than unrealistic images and messages are more likely to build both stakeholder and public trust in AAM technologies. Furthermore, local and tribal governments need reliable and informed guidance on realistic risks and hazards to build safety systems to support the vertiports. For example, vertiports need appropriate fire codes and infrastructure to mitigate risks associated with AAM fires, and local communities need to have human resources trained, equipped, and prepared to attend to a fire emergency at a UAM vertiport. This type of emergency preparedness can only be developed from proactive data sharing, honest conversations, realistic expectations, and an environment of industry trust and collaboration.

The aforementioned are some of the possible practical implications of the study's results; by translating the emergent themes into actionable insights, these results may contribute to the faster development of a more resilient, collaborative, safer, and more effective advanced air mobility industry.

Limitations of the Findings

There are several limitations of the qualitative data collected in this study. Some limitations are inherent to most qualitative studies that interview human subjects, and other limitations are specific to this study. The limitations of the findings for this study include the potential for bias, both on the part of the researcher and those who assisted the researcher, but also the generalizability of the findings, time constraints, data replicability, the capacity to quantify the results, participant's desire to be perceived as socially desirable, standardization of each of the interviews, and the potential for missing information or themes. Another limitation was the tests for normality of the Pearson's correlation coefficient, or word similarity index, which violated the Kolmogorov-Smirnova and Shapiro-Wilk tests for normality, contained in Appendix G. These are all briefly discussed in the following paragraphs.

Subjectivity and Bias, Limitations of the Coders, SMEs, and the Researcher. This study employed independent subject matter experts, independent coders, the research committee, and other strategies in the research design to limit bias as much as reasonably practical. However, as qualitative research relies on data interpretation, researchers' biases and subjectivity can influence the analysis and interpretation of emergent themes. The researcher's background, experiences, and beliefs can shape how they perceive and interpret the data, potentially leading to biased findings. Although this study employed vigorous mitigation strategies to limit human bias, it likely exists within the findings.

Qualitative Generalizability. As in this study, qualitative research often involves a small sample size, and the findings may not be easily generalizable to the larger global UAM population. This qualitative study aimed not to make statistical generalizations but to provide in-depth insights into a specific context. The sample was limited to 20 participants working within the UAM vertiport industry in the United States; these participants are considered experts in their field and occupy senior positions within the organizations they represent. These individuals were purposively chosen for their experience and leadership presence within the UAM vertiport industry; the researcher acknowledges that the UAM vertiport industry represents a small but rapidly growing aviation sector; therefore, these individuals represent a smaller and somewhat specialized sector of the aviation industry.

Time Constraints. This study focuses on the emerging advanced aviation industry, specifically UAM vertiport safety systems, at a snapshot in time, specifically during 2022 and 2023, when the participant interviews were conducted. The industry is moving at an extraordinarily fast pace, and there have been advancements within the industry within the time taken to complete this dissertation, as follow-up conversations with stakeholders since data collection have indicated that some stakeholders are forming alliances to share data and gain market share in some areas, recognizing the way forward is through partnerships. However, general indications seem to point to an industry that has yet to initiate a unified safety effort.

Data Replicability. Due to the highly context-dependent nature of this qualitative research study, replicating the design in a different setting may not yield the same results. Although the instrument and the design were methodically implemented, the findings are specific to the particular context and participants involved. The industry is also evolving rapidly, and the concerns of stakeholders today may be somewhat different once UAM vertiports become an operational reality in the United States. The findings from this research focused on stakeholders in the United States; it would be interesting to replicate this study in other countries or industries and compare the results.

Quantifying the Results. The results from this study are unlike quantitative research results; the data is highly contextual, capturing complex human perspectives that are influenced by sentiment, bias, feelings, and their unique sphere of lived experiences. However, the goal of this research was to take the findings and categorize them into likely emergent themes to build a theoretical framework that may be used for future quantitative data analysis. It may be challenging to quantify these themes, and more research is needed to arrive at quantitative variables to perform statistical analyses.

Participant Social Desirability Bias. The study participants know they were chosen to participate in this research as they have a leadership profile within the industry. Each participant's selection was purposeful to gain the quality of the insights from their transcripts, supporting the emergence of highly contextual data. Although their participation in this study was confidential, they may have provided responses they perceived as socially desirable or acceptable. Although the researcher reassured each participant of their anonymity, there was still potential for the participant to provide biased or incomplete information. An example of this was the hesitance of the female participants to have their perceptions and experiences of sexism officially recorded in the transcripts; in fact, every female participant expressed that they were experiencing sexism to varying degrees, along with the negative sentiment and affect associated with disgust, annoyance, and frustration.

Standardization of the Interviews. Interviewing participants for qualitative research heavily depends on the skills and expertise of the researcher; additionally, other factors that can influence the standardization of the interviews include the quality of the internet connection, background noise, external time or other pressures on the participant, and fatigue or health. For example, one of the participants had to break off the interview to attend to an external matter before returning to complete the discussion with the researcher a few hours later; this may have broken the participant's concentration, and information may not have been gathered. Another participant was fatigued and recovering from a cold; however, they wanted to continue. These factors may have influenced the participants' responses to the researcher's questions.

Potential for Missing Themes. Despite efforts to be standardized and comprehensive, essential themes that could provide further valuable insights into participant perceptions may have been missed or overlooked. While the research instrument was designed with knowledgeable subject matter experts, it is possible that this can happen due to preconceived notions and biases towards the emergent nature of the advanced air mobility industry or limitations in the data collection process, as mentioned in the previous paragraph.

Violation of Normality. If a word similarity index violates normality tests, it may seem unconventional in traditional statistical analyses, as these tests are important in many quantitative studies. Qualitative research often deals with non-parametric data or data that does not need to conform to parametric assumptions. However, qualitative phenomenological research focuses on capturing and interpreting the essence of lived experiences rather than conforming to strict statistical assumptions (Bazeley, 2013; Creswell & Creswell, 2018; Creswell & Miller, 2000; Saldaña, 2021). In this study, the length of transcripts varied, from over 10 thousand words to as little as just three thousand words, with the average being around six thousand words. The size of the transcript was not an indication of the quality or contextual richness of the data. Because the tests were conducted, the results were reported for transparency, rigor, and context-appropriate interpretation of this research process and reporting; the results are included in Appendix G.

Recommendations for Future Research

This research is the only known study to comprehensively investigate UAM vertiport stakeholders' perspectives of operational safety and how they perceive the other stakeholders who are also solving the challenges of the emerging UAM industry. This study provided insight into how these UAM vertiport stakeholders will likely choose who to collaborate with, what influences their decision-making, and how they perceive their relationships with other stakeholders, regulators, and the communities supporting vertiport vertiport operations. The data allowed for the discovery of three emergent themes; however, the codes and sub-codes that emerged from the data offer significant opportunities for further research. These are briefly discussed in the following paragraphs.

Commercial Pressure. More research is needed to fully understand the magnitude of child codes that contribute to within-industry trust, in particular, to gain a deeper understanding of the effects of commercial pressure on the emerging aviation industry. Commercial pressure was identified in the data as a significant contributor to a perceived lack of within-industry trust and seemed to be related to stakeholders' reluctance to share data and operational information that may impact safety. Commercial pressure is often described in the data as coming from investors' and public perceptions and expectations. Commercial pressure within the advanced aviation industry has not been examined as it has been in traditional aviation, and given the impact commercial pressure has on accidents, it is worthy of further investigation as a potential causal factor in future advanced aviation accidents.

Traditional and Advanced Aviation Cultural Friction. More needs to be understood about the factors contributing to the friction between traditional aviation safety culture and the innovative Silicon Valley culture. Safety culture is a multi-faceted and often challenging topic for safety professionals to navigate. Safety culture can take years to establish and directly impacts an organization's safety performance. Future research will likely continue to find enablers to generate a new and evolved culture for the Advanced Air Mobility industry, which may need flexibility and adaptation of existing norms and standards to encompass increasing levels of the human automation and autonomy interface.

Identified Vertiport Problems. The data from this study indicates that the location of the vertiport seems to be a prominent source of worry and concern for UAM stakeholders; in particular, more research is required to understand the technical aspects of vertiport location, including transitional flight characteristics of the approach, landing, and take-off and climb our phases of flight from the vertiport. Finally, this aspect of future research may help stakeholders and regulators to understand achievable and data-driven approaches to aircraft movements, industry best practices, and standards.

Transitional Flight Characteristics and Aircraft Uniformity. Many stakeholders point to a perceived lack of data and modeling resources to support understanding transitional lift and the transitional flight component of the take-off and landing of the eVTOL aircraft at the UAM vertiport. Transitional lift in vertical takeoff and landing (VTOL) aircraft refers to the phase when the aircraft transitions between vertical and horizontal flight modes. In this study, some research and development stakeholders, and several from the Federal Government category, expressed that this phase introduces specific hazards that need to be further investigated. Hazards associated with a transitional lift in VTOL aircraft include perceptions that there appears to be no standardization or commonality between the eVTOL aircraft, therefore making the design of safety systems for UAM vertiports complicated in the absence of aircraft uniformity or some industry guidance and standards.

Lack of aircraft uniformity was also described by some stakeholders as a source of potential concern, making the design of approach and landing flight paths and their corresponding ground paths difficult to plan as each aircraft will perform differently. The transition from vertical to horizontal flight requires adjustments in power settings, and there was concern about the differences in power and propulsion types of the various eVTOLs that may be using each vertiport, which gave rise to participant expressions of the lack of data about factors such as the effects of rotor disk loading and vortex ring states. Current vertical take-off and landing aircraft are susceptible to entering a vortex ring state, also known as settling with power, during descent. This occurs when the aircraft descends into its own downwash, leading to a loss of lift. Related to this is rotor wash, generated during vertical takeoff and landing, which can create turbulence and have an impact on the stability of nearby aircraft, especially during the transition phase. These effects pose risks to the VTOL aircraft and other nearby vehicles operating into and out of the vertiport.

Generic eVTOL Flight Path Modeling. The challenge the industry is currently facing is that this data does exist for specific eVTOL aircraft; however, this data is often proprietary to the original equipment manufacturer – future research may use computer simulations and machine learning to develop a generic eVTOL aircraft to help provide reliable data models for vertiport developers and safety professionals to design vertiports for optimum safety for high volume operations. Relating to the high throughput volume of UAM vertiport traffic, many participants expressed significant concern about the lack of actual data, the expectations that UAM vertiports will need to have a high throughput of aircraft (movements per hour) and that with limited data on the transitional lift, aerodynamic characteristics and lack of aircraft uniformity safety will be compromised.

Vertiport Wind and Weather. Additionally, limited research has been conducted on the local environment and wind conditions, including gusts and crosswinds, which can significantly impact the transitional lift phase. Sudden changes in wind direction or intensity can impact the stability and control of the aircraft, requiring skilled pilot input to manage these conditions. Participants in this study expressed that more research into local wind and weather phenomena is required before establishing a UAM vertiport site. Environmental factors, such as visibility, precipitation, and low cloud cover, can complicate the transitional lift phase and further complicate arrivals and departures at UAM vertiports.

Human Autonomy Integration. Higher levels of automation and the unique flight characteristics into and out of a UAM vertiport will require somewhat different pilot involvement and decision-making. Limited research on UAM pilot workload for these increasingly automated aircraft is available, especially during critical phases of UAM transitional flight, which may point to potential human autonomy integration errors and failings. Additionally, more research is needed to fully understand the UAM stakeholder's perceptions of autonomy and how these systems are monitored and integrated; questions such as the level of autonomy, human authority, and human accountability for autonomy are among the many areas yet to be studied further.

The Effects of Sexism and Gender Bias. The interviews of all female participants in this study involved expressions of sexism and gender bias. Although this data was not included in the transcripts except for one participant, the appearance of sexism within the data may indicate that sexism is a shaping factor in UAM vertiport's development. This would not be surprising, as sexism and gender bias have historically been shown to be a significant factor in the traditional aviation industry. This topic may be worthy of future research to help develop awareness and strategies to support a more inclusive and diverse industry to support a more innovative and generative safety culture.

Final Researcher Conclusion and Reflection

In concluding this qualitative dissertation on the perspectives of UAM vertiport stakeholders, it was surprising to uncover the cultural dynamics and trust issues within the advanced air mobility (AAM) industry. I reflect on the unexpected yet enlightening results that have emerged from this research journey. The exploration into emergent themes, specifically the cultural friction between traditional aviation stakeholders and those in the AAM sector, the observed lack of within-industry trust, and the prevalent fear of unknown risks have illuminated a nuanced landscape that demands attention, careful consideration, and the opportunity for further research.

It was exciting to work with the richness of the data, and the depth of insights gained from participants has provided a comprehensive understanding of the current challenges within the AAM industry and uncovered layers of complexity that were not initially anticipated. The surprising nature of these findings underscores the importance of qualitative research in capturing the subtleties and intricacies of human experiences, perspectives, and interactions.

As a researcher, I hope that this study serves as a foundational stepping stone for future investigations into establishing and operating advanced air mobility vertiports. The identified themes should not be viewed in isolation but rather as interconnected components shaping the industry's culture, relationships, and risk perceptions. It is my aspiration that this research sparks curiosity and further exploration, prompting future students, scholars, and practitioners alike to delve deeper into the intricacies of these emergent themes.

The potential implications of this study extend beyond the boundaries of this dissertation. Understanding and addressing the cultural frictions, fostering trust within the industry, and mitigating the fear of unknown risks are critical for the sustainable growth and successful integration of AAM technologies. The hope is that future researchers will build upon these insights, refining and expanding the theoretical framework established here to inform strategies, policies, and practices within the AAM community.

In conclusion, the results obtained from this qualitative research journey signify the richness of the AAM industry's landscape and the potential for positive transformation into a new type of aviation safety culture that is resilient, innovative, and flexible. As we pave the way for the future of advanced air mobility, let this dissertation serve as a catalyst for ongoing dialogue, research, and innovation, propelling the industry toward a safe, collaborative, and harmonious future.

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Appendix A

Applications to Conduct Research

A1

Researcher's Human Subjects Researcher Certification (Student and Researcher) and, Responsible Conduct of Research Certification.


CITI PROGRAM

Completion Date 19-Nov-2022
Expiration Date 19-Nov-2025
Record ID 52352379

This is to certify that:

Tracy Lamb

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

Group 3: Students
(Curriculum Group)
Human Subjects: Students
(Course Learner Group)
2 - Refresher Course
(Stage)

Under requirements set by:

Embry-Riddle Aeronautical University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w7b0c484c-b09c-43ec-8d3a-cbe2a67fa742-52352379


CITI PROGRAM

Completion Date 19-Nov-2022
Expiration Date 19-Nov-2025
Record ID 52352378

This is to certify that:

Tracy Lamb

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

Group 1. Researchers
(Curriculum Group)
Human Subjects: Researcher
(Course Learner Group)
2 - Refresher Course
(Stage)

Under requirements set by:

Embry-Riddle Aeronautical University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?wec9571b8-8f73-4795-b770-92085b4517cf-52352378


CITI PROGRAM

Completion Date 19-Nov-2022
Expiration Date N/A
Record ID 35051624

This is to certify that:

Tracy Lamb

Has completed the following CITI Program course:

Not valid for renewal of certification through CME.

Responsible Conduct of Research (RCR)
(Curriculum Group)
Social and Behavioral Responsible Conduct of Research Course 1.
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

Embry-Riddle Aeronautical University

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?wea8852be-06e0-4237-bc9c-520bb5bddd38-35051624

A2

IRB Application to Conduct Personal Interviews

Background and Purpose:

Urban Air Mobility (UAM) is an emerging industry. A 2018 market study conducted by the Booz Allen Hamilton (BAH) firm on behalf of NASA found that the potential UAM market demand could be worth $500 billion USD. While the safety of flight is a critical element of UAM, the safe operations of UAM aerodromes (vertiports) will involve more than just flight safety. Current literature indicates that stakeholders have identified many known or apparent challenges and barriers to operating vertiports; however, few studies address *how* and *why* stakeholders perceive these challenges, their specific concerns, perspectives, or their preferences. These gaps are critical to understanding potential latent challenges that may be designed into vertiport safety systems. Understanding stakeholders' perspectives at a granular level will provide transparency on how they intend to prioritize, manage, and integrate their specific concerns and experiences towards planning for operational safety at high-density vertiports. Therefore, the purpose of this study is to identify and explore emergent themes of operational safety of UAM at vertiports focusing on the Stakeholder Perspective.

Time:

Approximately 60 minutes

Design, Procedures, and Methods:

This project will include a *personal interview*. Participants will answer questions in a personal interview either; (a) in person, (b) via telephone, or (c) on a virtual meeting platform. The interview questions are attached. The interview's purpose is to discover insight into UAM stakeholders' concerns and feelings related to the operations of UAM vertiports. This study is non-experimental qualitative research with both a narrative and phenomenological. The participants' critical consciousness is the study's central tenet and value proposition; thus, using a personal interview approach will support this objective. To complete the study, the participants must be at least 18 years old and identified as having a stakeholder interest in UAM vertiports. Participants' personal information will be kept confidential, and any identifying information collected through the interview will be 'coded' as a number and date. The audio of interviews will be recorded but destroyed once transcribed into a Word document. Participants will sign the consent form before the interview begins.

Measures and Observations: What measures or observations will be taken in the study?

The outcome findings of interest in this study will be the emergent codes and themes of the UAM stakeholder viewpoint. These may also be influenced by possible variables such as stakeholder demographic information, stakeholder category, and other factors that may emerge from the open-ended interview questions. These factors will be coded, and their frequency and connections analyzed to determine emergent themes that form the critical consciousness of UAM stakeholders relating to vertiport operational safety.

If any questionnaires, tests, or other instruments are used, provide a brief description:

A copy of the instrument [interview questions] is attached for IRB review. Also attached is the announcement of the interview and the interview debrief.

Participant Population and Recruitment Procedures: Who will be recruited to be participants, and how will they be recruited? Any recruitment email, flyer or document(s) must be reviewed by the IRB. Note that except for anonymous surveys, participants must be at least 18 years of age to participate.

The population of interest is UAM stakeholders; these are individuals who work for companies, organizations, or governments that have an active role in UAM and will be using vertiports in the United States. An invitation to participate in this study will be extended via email to members of UAM stakeholder organizations through the network of collaborative working groups organized by NASA, Alliance Safety Systems Uncrewed Research Excellence (ASSURE), and ICAO. Participants who are willing to volunteer their time for the interview will be sent the consent form to be signed and returned. The researcher will then schedule the interview on a virtual platform (for example, Teams).

Risks or Discomforts: Describe any potential risks to the dignity, rights, health or welfare of the human subjects. All other possible options should be examined to minimize any risks to the participants.

This proposed study is not anticipated to pose any greater risk than normal daily activities.

Benefits: Assess the potential benefits to be gained by the subjects as well as to society in general as a result of this project.

There is no direct benefit to the participant other than what may be gained from reflective insights from answering researcher questions. However, their participation will have helped contribute to the advancement of knowledge in the field. The researcher seeks to learn more information into the critical consciousness of UAM stakeholders that are influencing possible outcomes to operational safety at vertiports.

Informed Consent: Describe the procedure you will use to obtain the informed consent of the subjects. How and where will you obtain consent? See Informed Consent Guidelines for more information on Informed Consent requirements.

A copy of the consent form and the interview announcement will be emailed to the participants. The Consent Form is to be signed and returned before the interview begins. As part of the consent form, they will also confirm that they are at least 18 years of age.

Confidentiality of Records: Participant information must be anonymous and confidential. Participant names and other identifying demographics will be de-identified. Publication of the data will not include any identifying information. Once the audio recording of the interview is transcribed, the recording will be deleted.

Confidential.

Names or any other identifying demographics will be coded into the interview transcription by the researcher, only the researcher will have access to raw audio information which will be destroyed after transcription. The researcher will be manually transcribing the audio files for quality and accuracy control. Publication of the data will not include any identifying information.

Privacy: Describe the safeguards (including confidentiality safeguards) you will use to minimize risks. Indicate what will happen to data collected from participants that choose to "opt out" during the research process. If video/audio recordings are part of the research, describe how long that data will be stored and when it will be destroyed.

The participant’s confidentiality will be protected, and participants also have the option to opt-out of the interview. If they withdraw from the interview prior to completion, their data will be destroyed immediately.

Economic Considerations: Are participants going to be paid for their participation?

No

A4

IRB Informed Consent Forms for Personal Interviews

INFORMED CONSENT FORM

UAM Stakeholder Interview: Vertiport Operational Safety

Purpose of this Research: We would greatly value your participation in this research project for the purpose of identifying and exploring emergent themes of operational safety of UAM at vertiports focusing on the stakeholder perspective. There is one part to this study: a personal interview that will be audio recorded about your specific challenges, concerns, perspectives, and preferences of operational safety at vertiports, and the second part is a focus group where a vertiport scenario is discussed with other stakeholders who are participating in the study. The completion of the interview will take approximately 60 minutes, and it will be audio recorded. This consent form is for the ***personal interview***.

Eligibility: To be in this study, you must be a resident of the U.S., at least 18 years of age, and work for an organization, company, group, or government that has an interest in UAM and vertiports.

Risks or discomforts: The risks of participating in this study are no greater than what is experienced in daily life.

Benefits: While there are no direct benefits to you as a participant other than what may be gained from reflective insights from answering researcher questions, your assistance in this research will have helped contribute to the advancement of knowledge in the field. The researchers seek to gain more insight into the critical consciousness of UAM stakeholders that are influencing possible outcomes to operational safety at vertiports.

Confidentiality of records: Participant confidentiality is of the greatest concern to the researchers. No identifying data will be collected during this phase of this research study aside from the audio recordings. There are no questions that would reveal the participant's identity. Once the data analysis has been completed, the audio files will be destroyed. Your individual information will be kept confidential. Only the primary researcher, and the dissertation chair, will have access to this consent form which is the only personally-identifying information about your participation in the study. The publication of the data will not include any identifying information. Your information and interview answers will be de-identified and assigned codes. Information and audio files collected as part of this research will not be used or distributed for future research studies.

Compensation: You will not receive compensation for taking part in this study.

Contact: If you have any questions or would like additional information about this study, please contact Scott Winter, scott.winter@erau.edu. For any concerns or questions as a participant in this research, contact the Institutional Review Board (IRB) at 386-226-7179 or via email teri.gabriel@erau.edu.

Voluntary Participation: Your participation in this study is completely voluntary. You may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Should you wish to discontinue the research at any time, no information collected will be used.

Participant Privacy: Any personal information that can identify you will be removed from the data collected, and this data will not be used or distributed for future research studies.

CONSENT. By signing below, I certify that I am a resident of the U.S., I understand the information on this form, and I voluntarily agree to participate in the study. I further verify that the researcher has answered any and all questions I have about this study.

Participant's Signature   Date

Participant's Printed Name

Researcher's Signature   Date

A5

IRB Invitation for Volunteering for the Personal Interview

Email invitation to known or introduced potential participant

CC: Dr. Scott Winter (Dissertation Chair) Winter, winte25e@erau.edu

Dear XYX,

Thank you for expressing interest in voluntarily participating in my doctoral research interview. Your participation is valuable and will greatly assist in identifying and exploring emergent themes of operational safety of UAM at vertiports focusing on the stakeholder perspective.

There is one primary part to this study: a personal interview that will be audio recorded about your specific challenges, concerns, perspectives, and preferences of operational safety at vertiports. The completion of the interview will take approximately 60 minutes, and only the audio from the interview will be recorded. Therefore, you are not obligated to answer all the researcher's questions.

If you are willing to participate, you will be sent a separate email with the attached 'Informed Consent' form. This consent form has more detailed information and is required to be completed and returned just prior to the interview. The interview time will be set at the time and date that suits your schedule. Your participation is entirely voluntary, and I appreciate your support of this research effort.

Best regards
Tracy L. Lamb.

Ph.D. Candidate Embry-Riddle Aeronautical University

A6

Participant Debrief

UAM STAKEHOLDER STUDY DE-BRIEF

Purpose:
The purpose of this study was to identify and explore emergent themes of operational safety of UAM at vertiports focusing on the stakeholder perspective. You were asked a series of questions relating this topic, and there were no right or wrong answers as it is a reflection on how you truly feel and the view from your unique perspective. The final questions included demographic information to assist with the research. The interview was planned to take approximately 60 minutes and was conducted either via telephone, video call or in person as appropriate or convenient for both you and the interviewer.

How was this tested?
In this study, you were asked several questions regarding your thoughts, concerns and challenges relating to your role in UAM and your perspectives of vertiport safety. The transcripts of the interviews and the focus group will be analyzed, de-identified and coded to better understand these factors. The researcher will try to identify emergent codes and themes that may influence how operational safety systems at vertiports may support stakeholder needs.

Hypotheses and main questions:
This study is non-experimental qualitative exploratory research, approached through the phenomenological and narrative perspective using participant action as the design. The main research question for this study is *What are the emergent themes associated with stakeholders perspectives relating to operational safety at vertiports*?

Why is this important to study?
The researchers seek to learn more information about the perceptions of UAM stakeholders that are influencing possible outcomes to operational safety at vertiports. The findings of this study may assist vertiport designers, fleet operators, providers of UAM services, local and state governments, and other stakeholders in designing safety systems to better serve the needs of stakeholders, hereby hoping to make safety systems more intuitive, user friendly, and fit for purpose.

What if I want to know more?
If you are interested in learning more about this study, you may consult:

Scott R. Winter: 386.226.6491, winte25e@erau.edu

If you have concerns about your rights as a participant in this experiment, please contact the Teri Gabriel, ERAU IRB, at (386) 226-7179, teri.gabriel@erau.edu.

Thank you again for your participation.

Appendix B

Master Research Log

The full master research log is a zip file containing supporting documents, separate spreadsheets, and a collection of supportive spreadsheets from the analysis phase four. The master research log's main spreadsheet format is illustrated below. The MRL consists of the following data fields: (a) date, (b) primary MRL Element (memo, journal note, or participatory action), (c) Narrative content, (d) researcher concurrence, (e) SME concurrence, and (f) post reflective notes. Additional tabs include the main MRL legend, reflective questions, and stakeholder lists.

B1

	A	B	C	D
1	**Date**	**MRL Element**	**Narative Content (Change/Challenge/Issue…)**	**Post reflective notes**
2		Memos		
3		Reflection		
4		Coding		
5		Theme		
105				

MRL Legend | MRL main Page | 9 Validity Tools | NASANUAIRStakeholder List | Data Models

B2

Tesch's Eight-Step for Data Analysis

1 Get a sense of the whole. Read through all the transcriptions carefully and perhaps jot down some ideas as they come to mind.
2 Pick one document (one interview), which could be the most interesting, the shortest or the one on top of the pile. Go through it, asking yourself, what is this all about? Do not think about the "substance" of the information but rather its underlying meaning. Write thoughts in the margin.
3 When you have completed the task for several informants, make a list of the topics that emerged. Cluster together similar topics. Form these topics into columns that

might be arrayed as major topics, unique topics, and leftovers (they have no specific category).
4 Now take this list and go back to the data. Abbreviate the topics as codes and write the codes next to the appropriate segments of the text. Try out this preliminary organizing scheme to see whether new categories and codes emerge.
5 Find the most descriptive wording for your topics and turn them into categories. Look at reducing your total list of categories by grouping topics that relate to each other. Perhaps draw lines between your categories to show the interrelationships.
6 Make a final decision on the abbreviation for each category and alphabetize these codes.
7 Assemble the data material belonging to each category in one place and perform preliminary analysis.
8 If necessary, recode your existing data.

Appendix C

Measurement Instrument

C1

Measurement Instrument Participant Individual Interview Questions

6 Central Questions [RQ], 14 supporting questions.
1. Describe the current responsibilities of your role. **2. [RQ4]. How do your roles and responsibilities contribute to the safety efforts of the UAM ecosystem?** 3. What are the most significant safety issues/ responsibilities related to your role as a vertiport stakeholder? 4. What are the things stopping you from accomplishing these objectives?
5. [RQ2]. What are you currently experiencing at the forefront of the industry-wide problem-solving challenge? 6. What are the barriers to achieving your goals? 7. What is the most concerning factor when considering Vertiport's safe operation? What keeps you up at night? Why? 8.What resources do you currently use to guide your decision-making right now?
9. [RQ3]. How are you experiencing being at the forefront of the industry-wide problem-solving challenge? 10. What do you see as the actionable path forward? Why? 11.. How does this perception influence your goals or plans to achieve safe outcomes? 12.What are the resource gaps that you need but don't have?
13. [RQ5]. How do you perceive other stakeholders at other companies or organizations are experiencing problem-solving? 14. Do you think other UAM Vertiport stakeholders share these safety concerns? Why? 15. How does your organization prioritizes these safety concerns? Are they different from how other organizations prioritize their UAM Vertiport safety concerns?
16. [RQ6]. How likely are the interactions with other UAM stakeholder peers likely to influence your opinions on the design of safety processes, assumptions, and systems? 17. How active are you in industry working groups like the ones organized by NASA? Are these helpful to you? Why?
18. [RQ1]. What do you feel are unknown themes relating to stakeholders' perceptions, experiences, and opinions of operational safety at UAM vertiports? 19. What safety problems do you see that are not currently being addressed? 20. Is there anything else you would like to add for the researcher today?

Demographic Questions.

11. What is your age group: (20-30), (31-40), (41-50), (51-60), (61-70), (over 70).
12. What gender do you identify most with: (Male), (Female), (Non-binary), (Prefer not to answer).
13. What is your UAM vertiport stakeholder category: (R and D), (Fed Gov), (Aircraft and Component Manufacturer), (Airport and Local Municipalities).
14. Your title and role with this stakeholder are (title), (role).

15. How long have you been in this particular role: (less than one year), (1-2 years), (2-3 years), (3-4 years), (4-5 years), (5-6 years), (6-7 years), (7-8 years), (8-9 years), (9-10 years), (greater than ten years).
16. How long have you been with this particular stakeholder: (less than one year), (1-2 years), (2-3 years), (3-4 years), (4-5 years), (5-6 years), (6-7 years), (7-8 years), (8-9 years), (9-10 years), (greater than ten years).
17. What is your total annual salary: (less than 50K), (50-100K), (100-150K), (150-200K), (200-250K), (250-300K), (300-350K), (350-400K), (Greater than 400K).
18. Does your annual salary include the following: (none), (bonus), (company stock allocation), (performance incentives).
19. What is your current work arrangement: (onsite), (remote), (commute), (all of the above).
20. What is your highest education level: (high school), (higher education certification or diploma), (college or university degree), (master or advanced degree), (doctoral degree).

C2

Research Question Map to Instrument Questions

Central Research Question:

RQ1. What are the emergent or unknown themes relating to stakeholders' perceptions, experiences, and opinions of operational safety at UAM vertiports?

Supporting Research Questions:

RQ2.	**RQ3.**	**RQ4.**	**RQ5.**	**RQ6.**
What are the UAM vertiport stakeholders experiencing at the forefront of the industry-wide problem-solving challenge?	How are the UAM vertiport stakeholders experiencing being at the forefront of the industry-wide problem-solving challenge?	How do UAM stakeholders' roles and responsibilities contribute to the safety efforts of the UAM ecosystem?	How do these UAM stakeholders perceive their peers (stakeholders at other companies or organizations) experiencing problem-solving?	How likely are interactions with other UAM stakeholder peers likely to influence the participant's opinions on the design of safety processes, assumptions, and systems?

Research Instrument Questions RIQ:

1. Describe the current responsibilities of your role.	**RQ, 4**
2. What are the barriers to achieving your goals?	**RQ1, RQ2, RQ3, RQ4**
3. What do you see as the actionable path forward? Why?	**RQ1, RQ2, RQ3 RQ4**
4. How does this perception influence your goals or plans to achieve safe outcomes?	**RQ2, RQ3, RQ5**
5. What are the most significant safety issues/ responsibilities related to your role as a vertiport stakeholder?	**RQ6, RQ5, RQ4**
6. What is the most concerning factor when considering Vertiport's safe operation? What keeps you up at night? Why?	**RQ2, RQ3**

7. Do other UAM Vertiport stakeholders share these safety concerns? Why?	**RQ6, RQ5, RQ2, RQ3**
8. How does your organization prioritize these safety concerns? Are they different from how other organizations prioritize their UAM Vertiport safety concerns?	**RQ5, RQ6, RQ4**
9. How active are you in industry working groups like the ones organized by NASA? Are these helpful to you? Why?	**RQ5, RQ6, RQ4**
10. What resources do you currently use to guide your decision-making right now?	**RQ1, RQ5, RQ6, RQ4**
11. What are the resource gaps that you need but don't have?	**RQ1, RQ2**
12. What are the things stopping you from getting those things right now?	**RQ1, RQ2**
13. Is there anything else you would like to add for the researcher today?	**RQ1**

Appendix D

Pilot Test Viability Analysis

The Objective of the Pilot Study

The objective of the pilot study was to determine the instrument's effectiveness and its potential to answer the research questions. The result of the pilot study indicates that the instrument is fit for purpose and will likely be highly effective in gaining insight into the topic and answering the research questions.

Conduct

On December 27, 2022, one of the Four volunteer SMEs was interviewed for a duration of one hour and 15 minutes. The interview was recorded in accordance with the method outlined in the Research Proposal (phone interview recorded on the researcher's iPad in MP3 format). December 29 the recording was manually transcribed into a word document. Transcribing and accuracy editing time took approximately 6 hours. On December 30, the researcher uploaded the transcript into the Dedoose qualitative research platform for preliminary coding to estimate the instrument's effectiveness and viability. Demographic data was not assessed nor captured as part of the pilot.

Analysis

The preliminary analysis revealed a total of 42 Codes in total, of which Nine were Parent Codes and 31 were Child Codes. The codes were applied 278 times from 69 excerpts of the single transcript. It should be noted that codes established in the pilot may not be the same as those that emerge from the study participants—this analysis aimed to assess the instrument's effectiveness and utility. The following analysis indicates the instrument will be effective in collecting data to answer the research questions.

Figure D1

Pilot Study Code Analysis

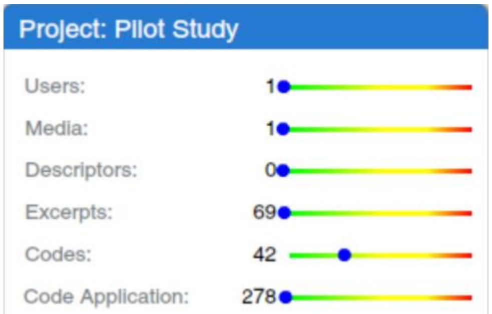


Figure D2

Parent and Child Codes from the Pilot Transcript

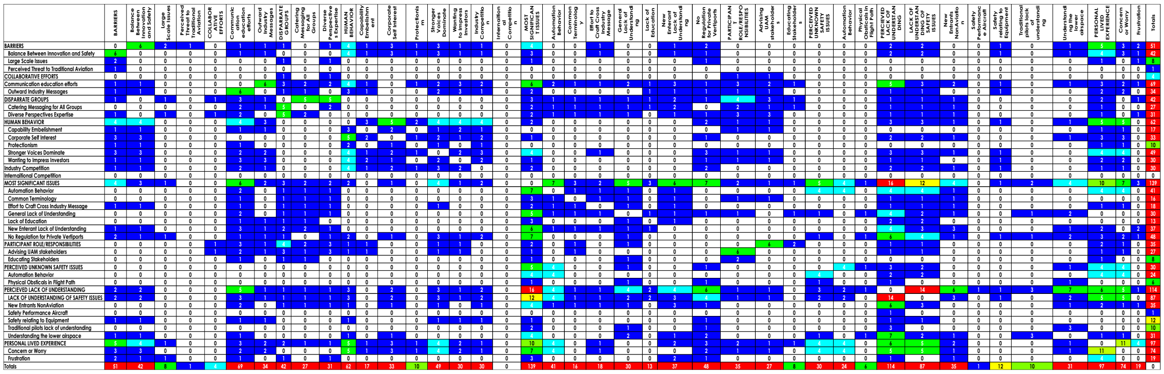
Codes and Sub-Codes (Parent & Child Codes)
1. BARRIERS
2. Balance Between Innovation and Safety
3. Large Scale Issues
4. Perceived Threat to Traditional Aviation
5. COLLABORATIVE EFFORTS
6. Communication education efforts
7. Outward Industry Messages
8. DISPARATE GROUPS
9. Catering Messaging for All Groups
10. Diverse Perspectives Expertise
11. HUMAN BEHAVIOR
12. Capability Embellishment
13. Corporate Self Interest
14. Protectionism
15. Stronger Voices Dominate
16. Wanting to Impress Investors
17. Industry Competition
18. International Competition
19. MOST SIGNIFICANT ISSUES
20. Automation Behavior
21. Common Terminology
22. Efforts to Craft Cross-Industry Message
23. General Lack of Understanding
24. Lack of Education
25. New Entrant Lack of Understanding
26. No Regulation for Private Vertiports
27. PARTICIPANT ROLE/RESPONSIBILITIES
28. Advising UAM stakeholders
29. Educating Stakeholders
30. PERCEIVED UNKNOWN SAFETY ISSUES
31. Automation Behavior
32. Physical Obstacles in Flight Path
33. PERCEIVED LACK OF UNDERSTANDING
34. Lack Of Understanding Of Safety Issues
35. New Entrants Nonaviation
36. Safety Performance Aircraft
37. Safety relating to Equipment
38. Traditional pilots lack of understanding
39. Understanding the lower airspace
40. PERSONAL LIVED EXPERIENCE
41. Concern or Worry
42. Frustration

Figure D3

Dedoose Generated Code and Sub-Code Cloud

Figure 4

Co-Occurrence Coding Strip

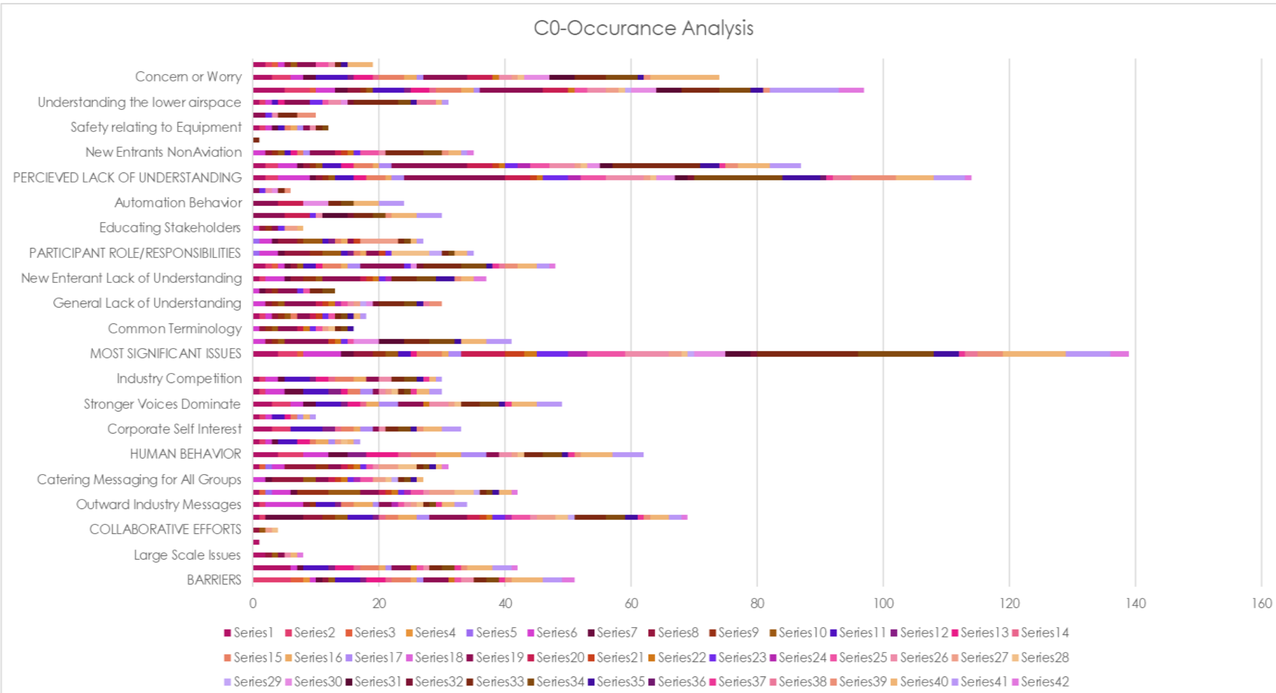


Conclusion

The preliminary analysis in Dedoose provided a cursory indication that the instrument will be both fit for purpose and effective in achieving answers to the research questions. Moreover, from the pilot test co-occurrence coding strip in Figure 4, above, and Figure 5 below, it can be seen that there will likely be overlapping codes representing emergent themes. Identifying these emergent themes is supported by rich context from the participants' lived experiences, especially those involving problem-solving, cross-group communication and understanding, descriptions of exhibited human behavior, and concerns about automation and trust behavior. In addition, many other interesting factors are likely yet to be discovered.

Figure D5

Graphical depiction of Co-Occurrence Analysis



Note. Pilot of transcript attached separately.

Appendix E

Directions for Coders

Purpose Statement

There are two main objectives for this proposed study. The first objective is ***to discover and explore emergent themes relating to UAM vertiport operational safety from the stakeholders' perspectives***, targeted at four specific UAM stakeholder categories; (a) academia and research and development, (b) the federal government, and (c) aircraft component manufacturers, (d) Airports and municipalities. These four stakeholder groups include organizations that have a direct or indirect role and responsibility in UAM and vertiports in the United States, and that responsibility flows to the individual roles within the stakeholder organizations.

A deep understanding of the ***perceptions, reflections, and opinions*** of the individual UAM stakeholders' experiences is required to identify emergent themes. Dialogic engagement through a personal interview is used to draw out and identify these emergent themes. The reader is reminded of the purpose of the central research question and inductive lines of inquiry aiming to learn; (a) *how* (b) *why* (c) *what* about the stakeholders' experience, their perceptions, reflections, and opinions to understand their perspectives.

The research also has an inductive purpose (2nd purpose), to provide a robust, repeatable qualitative design and a foundational platform upon which to build quantitative contextual variables for further investigation. ***Drawing out emergent themes from human perceptions, reflections, and opinions in prior studies has been used to solve societal problems associated with racism, academic, and school student engagement challenges, and issues with both civil and political engagement*** (Rappa & Jamil, 2020). However, this method has not yet been applied to UAM vertiport stakeholders and their challenges. Therefore, it is projected that this research may fill the existing gap in the literature and contribute to the body of knowledge in the UAM industry and academia.

Table E1

Stakeholder Categories

Stakeholder Category	Organization Examples	Target Sample Size [a]
1. Research & Development	NUAIR, AIAA, Aurora, ASSURE, HAI.	5
2. Federal Government	FAA (Next Gen, UAS, Vertiport), DOT, DOJ, NASA, NARI, NTSB.	5
3. Aircraft Component Manufacturer	Embraer [Eve], Airbus, Hyundai [Supernal], Boeing [Wisk], Joby.	5
4. Airport Management & Local Municipalities	Existing airport management, Local Municipalities (e.g., Oklahoma City, & Choctaw Nation, LA county, etc.)	5
	Total Participants	20

Definitions of Terms

Air Traffic Management	(ATM) The dynamic, integrated management of air traffic and airspace, including air traffic services, airspace management, and air traffic flow management safely, economically, and efficiently through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions. (FAA, 2020b; International Civil Aviation Organization [ICAO] Doc 4444 PANS-ATM).
Air Navigation Service Providers	(ANSP) Provide information for strategic ATC separation services for UAM operations (FAA, 2020b).
Community Business Rules	(CBR) Collaborative set of UAM operational business rules developed by the stakeholder community. Rules may be set by the UAM community to meet industry standards or FAA guidelines when specified. CBRs will require FAA approval (FAA, 2020b).
Conflict	A point in time in which the predicted separation of two or more aircraft is less than the defined separation minima (FAA, 2020b).
Constraint	An impact to the capacity of a resource. Constraints can be natural (e.g., weather), circumstantial (e.g., runway construction), or intentional (e.g., temporary flight restriction) (FAA, 2020b).
Cooperative Separation	Separation based on shared flight intent and data exchanges between operators, stakeholders, and service providers and is supported by the appropriate rules, regulations, and policies for the planned operations (FAA, 2020b).
Demand Capacity Balancing	(DCB) Flight intent adjustments during the planning phase to ensure that predicted demand does not exceed the capacity of a resource (e.g., UAM Corridor, aerodrome) (FAA, 2020b).
Human-on-the-Loop	(HOTL) Human supervisory control of the automation (systems) where the human actively monitors the systems and can take

	full control when required or desired (FAA, 2020b).
Human-over-the-Loop	(HOVTL) Human informed, or engaged by the automation (system) to take actions. Human passively monitors the systems and is informed by automation if and what action is required. Human is engaged by the automation either for exceptions that are not reconcilable or as part of rule set escalation.
Human-within-the-Loop	(HWTL) Human is always in direct control of the automation (systems).
Master Research Log	(MRL) The collection of researcher and subject-matter expert generated data from the study. Includes reflective journal notes, memos, concept models, and researcher tools.
Operational Tempo	The density, frequency, and complexity of operations.
Providers of Services for UAM	(PSU) An entity that assists UAM operators with meeting UAM operational requirements to enable safe and efficient use of UAM corridors and aerodromes. This service provider shares operational data with stakeholders and confirms flight intent.
PSU Network	A collection of PSUs with access to each PSU's data for use and sharing with their subscribers (FAA, 2020b).
Strategic Deconfliction	Deconfliction of UAM Operational Intent via advanced planning and information exchange (FAA, 2020b).
Subject-Matter Expert	(SME) An individual who has qualifications and specific knowledge in UAM and vertiports.
Tactical Separation	UAM operator responsibility for tactical conflict and collision avoidance (FAA, 2020b).
UAM Aerodrome	A location from which UAM flights arrive and depart (FAA, 2020b).
UAM Aircraft	An aircraft that can execute UAM operations.
UAM Corridor	An airspace volume is defining a three-dimensional route segment with performance requirements to operate within or cross where

	tactical ATC separation services are not provided (FAA, 2020b).
UAM Operation	The transport of people or goods from one aerodrome to another using UAM corridors.
UAM Operational Intent	Operation specific information including, but not limited to, UAM operation identification, the intended UAM corridor(s), aerodromes, and key operational event times (e.g., departure, arrival) of the UAM operation.
UAM Operator	The person or entity responsible for the overall management of a UAM operation; represents the organization that is executing the operation (FAA, 2020b).
UAS Traffic Management	(UTM) The manner in which the FAA will support operations for UAS operating in low-altitude airspace (FAA, 2020b).
UTM Operator	Operators conducting low altitude UAS operations utilizing UTM-specific services (FAA, 2020b).

List of Acronyms

AAM	Advanced Air Mobility
ADS-B	Automatic Dependent Surveillance-Broadcast
AGL	Above Ground Level
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
CBR	Community Business Rules
ConOps	Concept of Operations
DAA	Detect and Avoid
DCB	Demand Capacity Balancing
DEP	Distributed Electric Propulsion
eVTOL	Electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration
FAA ANG	FAA Organization – NextGen Program Office
HOTL	Human-on-the-Loop
HOVTL	Human-over-the-Loop
HWTL	Human-within-the-Loop
ICAO	International Civil Aviation Organization
LOA	Letter of Agreement
MRL	Master Research Log
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Airmen
PIC	Pilot in Command
PSU	Provider of Services for UAM
RID	Remote Identification (ID)
SAA	Special Activity Airspace
SDSP	Supplemental Data Service Provider
SME	Subject-Matter Expert
SWIM	System Wide Information Management
TFR	Temporary Flight Restriction
UAM	Urban Air Mobility

UAS	Uncrewed Aircraft System
USS	UAS Service Supplier
UTM	UAS Traffic Management
V2V	Vehicle-to-Vehicle
VTOL	Vertical Take-Off and Landing

Appendix F

Code Book

Parent / Child Code	Definition / Description / Example	Files	References
1. AFFECT	Substantial research has examined the relationship between emotion and its influence on decision-making (Forgas, 1995; George, 1991; Kahneman et al., 1982; Wright and Bower, 1992).	20	566
DISGUST	marked aversion aroused by something highly distasteful. EG. "…once the damage is done, once you've burned the city because you took money and built a vertiport that then couldn't be used…"	14	45
FEAR, WORRY, CONCERN	an unpleasant, often strong emotion caused by anticipation or awareness of danger. EG: "…every time I see drones flying near a heliport I think wow what a nightmare..."	18	252
FRUSTRATION, AGGRAVATION, ANNOYANCE	a deep chronic sense or state of insecurity and dissatisfaction arising from unresolved problems or unfulfilled needs. "there are so many other things to worry about um so it's pretty easy for me to stay up all night and get frustrated! – uhh and concerned…"	20	169
HAPPINESS, EXCITEMENT	A state of well-being and contentment: JOY : a pleasurable or satisfying experience. EG: … Its exciting, I wake up every day happy to go to work …"	18	70
SADNESS, DISAPPOINTMENT	affected with or expressive of grief or unhappiness :DOWNCAST: causing or associated with grief or unhappiness : DEPRESSING. Dismay.	9	21
SURPRISE	the feeling caused by something unexpected or unusual. E.g. "…Right, now there is something like 6000 heliports in the United States right now, of which 8 are for public use".	7	9
2. COMMERCIAL PRESSURE	Commercial pressure in aviation refers to the competition and financial pressures faced by airlines, manufacturers, and other aviation companies. Airlines are under pressure to maximize profits and minimize costs, which can lead to reductions in service quality, safety risks, and price competition. Manufacturers may be under pressure to cut costs or reduce development time, which can lead to quality issues or safety concerns. Pilots can suffer commercial pressure to fly unsafe conditions to meet schedules o	20	255
CORPORATE FAILURE NOT AN OPTION	The consequences of a corporate failure can result in the loss of jobs, financial ruin, and damage to the company's reputation. This may be expressed in the transcripts as closely related to impressing investors, producing unrealistic expectations or announcements, embellishing press releases or social media promotions or 'renderings'.	19	79
CORPORATE PROTECTIONISM	This code is for when the participant expresses that data or performance characteristics, or logistics and planning are not shared to protect the competitive edge, or secret sauce of the company.	15	38
MANIPULATION, PRESSURE ON LEGISLATORS	Described by some participants as 'Lawyering Up' and devoting a large portion of funds to convince legislators	12	45

	and the FAA to make regulations faster or to benefit themselves over other stakeholder organizations.		
POLITICAL PRESSURE ON REGULATOR	Described by some participants as educating Congress and devoting a large portion of funds to convince members of Congress to pressure local government and or FAA.	13	47
PUBLIC IMAGE PRIORITIZATION	producing unrealistic or highly stylized announcements, embellishing press releases or, social media promotions or 'fancy renderings'. Stronger voices dominate	12	41
3. GAPS AND LACKS	to be deficient or missing ; to be short or have need of something	20	812
EDUCATION OUTREACH	The participant expresses any lack of formal or generally accepted educational functions.	17	100
FUNDING AND FINANCE	Lack of monetary funding – lack of money	13	32
MODELING CAPABILITY, DATA	The lack of computer or data models to support the various concepts of UAM operations at vertiport modeling and simulation could also fall into this child node.	17	86
PERSONNEL, WORKFORCE	A workforce gap, or personnel gap, is identified to meet the operations in the UAM ecosystem and at vertiports.	14	50
REGULATIONS AND STANDARDS	Lack of regulations pertaining to vertiports, and UAM operations	20	182
TECHNOLOGY	Lack of technology to support the UAM operations at vertiports and also within the industry: modeling and simulation could also fall into this child node.	17	64
TERMINOLOGY STANDARDIZATIO N	A lack of unified or standard terminology for UAM and Vertiports.	16	82
UNDERSTANDING AVIATION, ADVANCED AVIATION		20	216
4. HIGHEST PRIORITIES	something is given or meriting attention before competing alternatives	20	736
CONSENSUS, CO OPERATION		18	123
DOMESTIC COMPETITION	Priorities to make a particular municipality, city, or OEM company a leader or lead the USA efforts and activities in AAM, UAM, and Vertiports.	5	11
GAINING COMPETITIVE ADVANTAGE	Any action, intention or expression by the participant to be the only company, municipality, or organization to able to provide services first, exclusively, or be the dominant provider.	14	66
GLOBAL COMPETITION	Priorities to make the USA a leader or lead the world efforts and activities in AAM, UAM, and Vertiports.	10	27
INVESTORS PERCEPTION	The priority is placed on the perception of investors who provide funding for OEM's, Municipalities, or other entities. This can include venture capitalists, private equity, government funding, or other investor sources.	18	91
PUBLIC PERCEPTION, EXPERIENCE	The priority of the participant or participant's organization to influence or manipulate the public's perception.	19	121
RETURN ON INVESTMENT	Although not in the MW dictionary, the ROI is generally accepted as the ratio of profit or 'break even' amount for a given year to the amount of capital invested or to the value of sales. Or, : the compensation accruing to entrepreneurs	19	133

	or investors for the assumption of risk in business enterprise as distinguished from wages or rent		
SAFETY	expressions of actions or efforts to / or show concern to protect against failure, breakage, or accident	20	164
IDENTIFIED VERTIPORT PROBLEMS	This parent code will cover any identified text that discusses the issues facing the actual vertiport operation. It is more focused than comments or text that deals with the broader AAM or UAM environment.	20	1122
AIRCRAFT UNIFORMITY	Many of the evtol aircraft in production today are very different in their design and performance capabilities. They are also different in the way they are going to land and take off have different receptacles for re-charging, some will be able to taxi after landing (they have wheels) some will not. Each OEM keeps the performance characteristics and features to themselves as 'proprietary' data. This code depicts when the participant expresses the need or observation about the differences between the aircraft	20	133
AIRCRAFT VORTICES	You will see this described in the transcripts, it is similar concept to rotor downwash, except that it is generated in flight, and the vortices remain in the air for some time depending upon the weather conditions. Also called wingtip or wake vortices. These can flip another aircraft inverted in flight if they come into contact with the vortices. Although usually associated with larger aircraft, wingtip vortices are how many birds are able to fly in formation for longer periods by taking advantage of the	11	37
CYBER, PHYSICAL SECURITY, PRIVACY	This code encompasses expressions of both physical and cyber security measures taken to protect a computer or computer system (as on the Internet) against unauthorized access or attack. Physical security and law enforcement, eg TSA. This code is also used when a participant mentions privacy as part of the security discussion.	9	29
FIRE RISKS, HAZARDS, CODES	This code reflects participant expressions of fire hazards, and these include building fire codes and standards, the risk of fire from lithium battery sources and charging, the risk of fire or explosion from aircraft refueling storage of fuel sources. This also includes the ability or lack thereof to contain fires, explosions, and personnel such as fire fighting equipment and teams to deal with fires.	7	22
LACK OF UNDERSTANDING OF VERTIPORT OPERATIONS	Lack of understanding of how operations are going to be conducted at UAM vertiports. The absence of a shared understanding of aircraft performance, regulations, zoning, movement or throughput of aircraft numbers per day or hour.	20	202
LOCATION OF VERTIPORT	The location of the vertiport needs to be profitable for the operator. This code is for participants who talk about the location of the vertiport in relation to it's viability, profitability, throughput or usage.	20	257
LOW ALTITUDE AND MICRO WEATHER	For the purpose of this study, low altitude weather refers to local weather in close proximity to the UAM Vertiport – also the local weather phenomenon on the approach or take-off path to the vertiport. This will usually be described as weather generated by wind vortices between	16	58

	buildings, urban canyons, local fog, temperature variations, and how the aircraft will behave.		
MUNICIPALITY EQUITY AND ACCEPTANCE	The acceptance and willingness of the community around a UAM vertiport to use UAM aircraft and have the Vertiport in close proximity to their dwelling or community group. Participants may express a lack of ‘regulations or zoning, however, this code also covers the “Not in my Back Yard” NIMBY phenomenon where by one community may be disadvantaged by having no access to a vertiport – while others may be disadvantaged by being subjected to more noise or other factors.	14	80
NIMBYISM	Acronym for "Not in My Back Yard". this code is allocated to expressions of direct mention of NIMBYISM or expressions of wanting UAM evtol, but not in certain areas, or neighborhoods - for example not in the rich areas, or not in my quiet neighborhood etc.	3	4
NOISE	Noise associated with the UAM aircraft taking off, operating or landing at vertiport	8	25
PHYSICAL OBSTRUCTIONS, OBSTACLES	For the purpose of this study, physical obstructions expressed by the participant will be, anything that has the potential to come into the flight path of the landing take off or en route phase of flight of the UAM. This may be buildings, trees, cell phone towers, power lines etc	15	67
ROTOR DOWNWASH, DISK LOADING	the downward component of thrust/lift produced by the rotor of a helicopter or electric vertical take off and landing aircraft (evtol). Rotor Downwash is also described as ‘disk downwash’. As a general rule, the more powerful the engine the greater the rotor downwash (expressed as disk loading); the higher the disk loading the more powerful and dangerous the downwash. Downwash can cause other aircraft or people to be blown off the landing surface, it has the power to tip over other aircraft nearby and dam	14	44
UNKNOWN RISKS	The participant indicates that there may be risks that are unknown, or they don’t know, or they recognize that there are risks they have not considered.	20	162
5. SAFETY CULTURE	Safety culture refers to the attitudes, behaviors, beliefs, values, and practices within an organization that prioritize (or fail to recognize) safety as a core value.	20	301
FRICTION, MISMATCH IN SAFETY CULTURES	When individuals from diverse industries come together, their unique cultures and practices may create differences and misunderstandings. This can result in friction or a mismatch, presenting unique challenges when trying to collaborate or work together.	19	97
SEXISM		1	3
SILICON VALLEY INNOVATION CULTURE	Silicon Valley is known for its innovation culture, which values creativity, risk-taking, and a relentless pursuit of growth and success. It is fuelled by a concentration of talent, venture capital, and funding opportunities, a willingness to embrace failure (fail fast) and learn from it. In Silicon Valley, entrepreneurs and innovators are encouraged to challenge the status quo and disrupt existing industries. Startups are often founded by young, ambitious entrepreneurs who are willing to take risks and pursue	18	141

TRADITIONAL AVIATION CULTURE	traditional aviation safety culture refers to the attitudes, beliefs, and practices that are prevalent in the aviation industry to ensure safety in flight operations is backed up by strict regulations and procedures (often promulgated from accidents and incidents where lives were lost) that must be followed to ensure the safety of everyone involved in the aviation industry. traditional aviation safety culture is a vital component of the aviation industry, ensuring that everyone involved in flight operations	15	56
6. STAKEHOLDERS PERCEPTIONS	The expression of a perception of themselves, their organization, and others in the UAM industry	20	579
AUTOMATION AND AUTONOMY ASSUMPTIONS	Comments or expressions of what they perceive themselves and others are doing about autonomy, highly automated functions. "they think the automation will take care of it" it will be safer because it will be automated".. comments about taking the human out of the equation.	16	92
NOVELTY ASSUMPTIONS	It is a new or 'start-up' industry, no one has done this before, the participant indicates they are in novel or new technology and make assumptions without having actual knowledge, data, or experience	20	235
RISK PERCEPTIONS AND ASSUMPTIONS	Reflected in stakeholder's comments, others are not considering risk, higher risk or others don't understand the risk. Assuming others are 'ignorant, 'This code if for expressions where 'others don't appear to understand' or be thinking or knowing risk factors.	20	250

Appendix G

Similarity Index Normality Tests

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Pearson correlation coefficient	190	100.0%	0	0.0%	190	100.0%

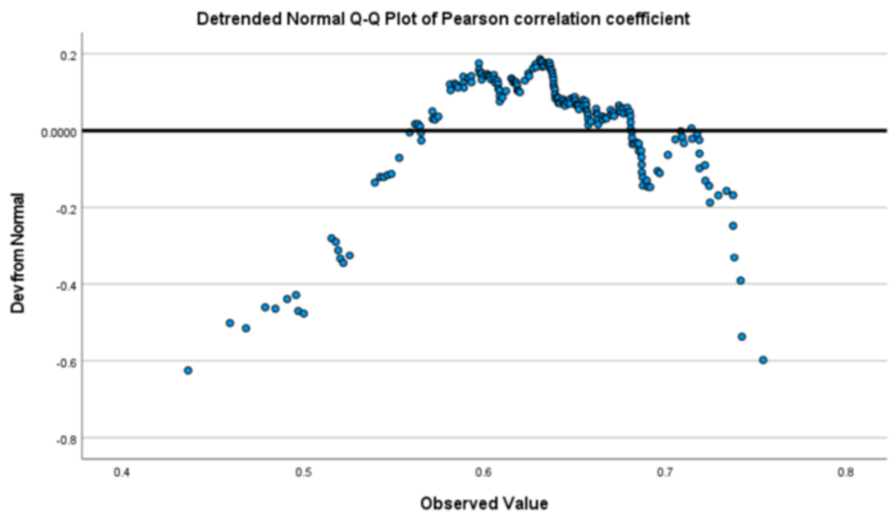
Descriptives

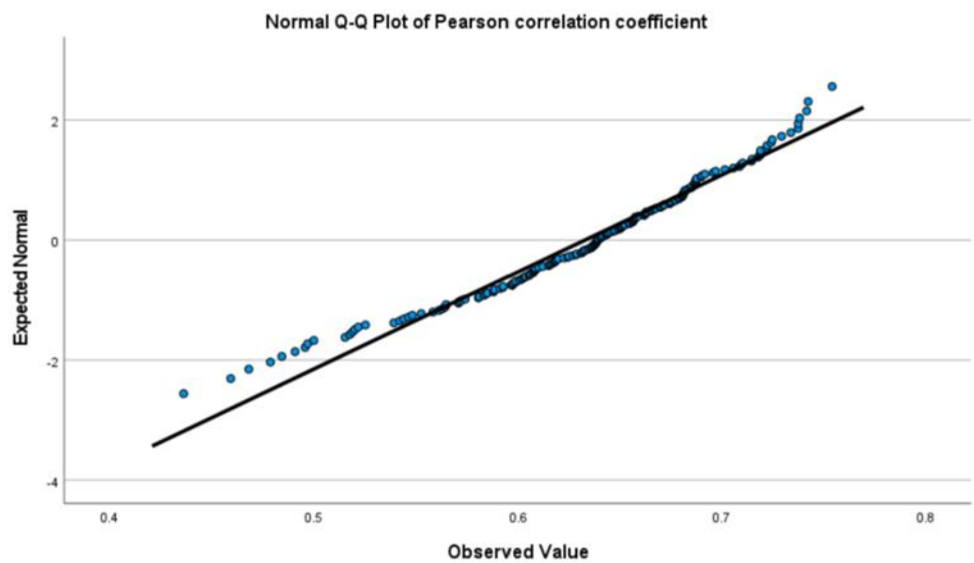
			Statistic	Std. Error
Pearson correlation coefficient	Mean		.63287014	.004478139
	95% Confidence Interval for Mean	Lower Bound	.62403658	
		Upper Bound	.64170369	
	5% Trimmed Mean		.63553415	
	Median		.63905100	
	Variance		.004	
	Std. Deviation		.061726882	
	Minimum		.436276	
	Maximum		.753977	
	Range		.317701	
	Interquartile Range		.077544	
	Skewness		-.654	.176
	Kurtosis		.410	.351

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pearson correlation coefficient	.076	190	.009	.970	190	.000

a. Lilliefors Significance Correction





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