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OBJECTIVES

The University Aviation Association publishes the Collegiate Aviation Review International throughout each calendar year. Papers published in each volume and issue are selected from submissions that were subjected to a double-blind peer review process.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education and research. Working through its officers, trustees, committees, and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aerospace industry. The University Aviation Association accomplishes its goals through a number of objectives:

- To encourage and promote the attainment of the highest standards in aviation education at the college level
- To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignment, and other professional contributions that stimulate and develop aviation education
- To furnish an international vehicle for the dissemination of knowledge relative to aviation among institutions of higher learning and governmental and industrial organizations in the aviation/aerospace field
- To foster the interchange of information among institutions that offer non-engineering oriented aviation programs including business technology, transportation, and education
- To actively support aviation/aerospace oriented teacher education with particular emphasis on the presentation of educational workshops and the development of educational materials covering all disciplines within the aviation and aerospace field

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02-05-2025

Student Perceptions of Meaningful Learning and Academic Performance in Aeronautical Courses: A Quantitative Study

Andrea L. Smith, Ph.D.
Liberty University

Current literature on the predictive correlation between a student's perceived course value and their end-of-course results utilizing the Course Valuing Inventory (Nehari & Bender, 1978) has not been studied in aeronautics education. While research investigating various attributes of academic success exists, quantitative studies specifically addressing predictive variables of course success related to end-of-course grades in aeronautics education do not exist. Given the results of quantitative data, aeronautics academia can strategically implement specific variables into course planning and designing to create academic content that appeals to aeronautic students. The purpose of this quantitative, predictive correlational study is to examine the predictive correlational relationship between the predictor variables (course valuing, cognitive content, affective-personal, and behavioral factors) and the criterion variable (end-of-course grade) for undergraduate aeronautical degree-seeking students at a large, accredited, faith-based, non-profit, private university in the southeastern United States with a large student population. The convenience sample consisted of 137 undergraduate aeronautics students. Data were analyzed using multiple linear regression. The study results showed no significant connection between the predictor variables (course valuing, cognitive content, affective-personal, and behavioral factors) and the criterion variable (end-of-course grade).

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Introduction

This research aims to answer the research question, "How accurately can end-of-course grade be predicted by the subscales of the Course Valuing Inventory (CVI) for an undergraduate aeronautical student?" The empirical significance of this study lies in its potential contribution to the humanistic educational theory. The practical significance of this study lies in its potential contribution to the predictive factors related to the personalization of course content based on student perceived meaningfulness of their educational experience. The literature review presents a thorough review of the literature related to this topic. This literature review opens with the theoretical framework. The theoretical framework is guided by Untari's (2016) humanistic educational theory, supported by Carl Rogers' (1969) humanistic worldview. Following the theoretical framework, a thorough review of the related literature is provided. Immediately following the literature review, the methodology used in this research study is addressed. The findings are then presented, emphasizing the predictability of end-of-course grade by measuring the student's perception of course value, cognitive content, affective-personal, and behavioral factors measured by the Course Valuing Inventory (CVI; Nehari & Bender, 1978). The discussion, limitations, and recommendations for future research are presented. This article ends with a conclusion that provides a summary of the article. The findings and results of this study could not support the connection between the predictor variables and the criterion variable among undergraduate aeronautical students.

Literature Review

The purpose of this study is to explore whether specific factors—course valuing, content learning, personal learning, and behavioral learning—can predict the end-of-course grades of undergraduate aeronautical students enrolled in non-flight, non-ground courses required for their pilot degree program. Grounded in humanistic educational theory (Rogers, 1969; Untari, 2016), which emphasizes the motivations behind human learning, this study examines how these predictor variables influence academic success. The literature review investigates both cognitive and non-cognitive factors related to academic performance, with a focus on how undergraduate students perceive the meaning and value of coursework unrelated to their degree program.

Theoretical Framework

Carl Rogers (1969) emphasized that man is primarily in control of every facet of his life, including successes and failures (Hatlevik & Hovdenak, 2020; Purswell, 2019; Untari, 2016). Man controls his choices, investments, and values, freely deciding what is good or bad for himself. While man has this control, choices can be influenced by upbringing and environment (Cooper, 2013; Rogers, 1969). Thus, control is directed by consciousness. The humanistic approach to life emphasizes that man has a conscious that dictates the good and bad of an experience.

Humanism

The humanistic approach emphasizes that man has a conscience that dictates the value of experiences. Man desires growth, fulfillment, and meaning from life. Rogers (1969) noted that conscience compels individuals to derive meaning from experiences. However, consciousness has limitations due to the fulfillment factor (George-Williams et al., 2019; Gupte et al., 2021; Rogers, 1969; Untari, 2016). How a man perceives an experience is shaped by whether his conscious desires are met (Nehari & Bender, 1978). Humans have self-directed awareness, and their consciousness influences their control over their environment. A man's reality is defined by his consciousness, making individualized reality difficult to observe. Although individuals create their reality, they can overcome influenced consciousness by finding personal value in experiences (Cooper, 2013; Purswell, 2019).

Humanistic Educational Theory

Humanistic educational theory draws from Maslow's (1968) needs hierarchy, Stenhouse's (1975) process-oriented curriculum, Knowles' (1980) andragogy, Freire's (1970) critical pedagogy, and Rogers' (1969) principles (Untari, 2016). The humanistic educational theory places the learner at the center of education. Humans determine their learning needs, design their paths, and apply knowledge as they see fit. Learning must fulfill internal needs and desires despite perceptions of usefulness. Humanistic educational theory emphasizes that learning must be self-directed and driven by a personal desire to derive meaning from experience (Untari, 2016).

Humanism in Humanistic Educational Theory. Humanism posits that man, as a product of nature, also controls it. The humanistic educational theory asserts that man governs his learning by combining control over nature with innate learning ability. Humanism positions man as the creator and owner of his education (Cooper, 2013; Untari, 2016). The humanistic educational theory is grounded in humanistic principles. “The educational principles of humanistic educational theory are based on the assumption that human beings have consciousness, understanding of self and reality, the ability to control their actions, and objectives for all activities” (Untari, 2016, p. 71).

Humanistic Educational Theory in a Learning Environment. According to Maslow (1968), man has an innate desire for self-actualization (Cooper, 2013; Purswell, 2019; Untari, 2016). Students must interpret experiences as tangible and purposeful to fulfill self-actualization. Learning experiences should elicit meaningful behaviors that align personal effort with learning outcomes. Considering the elements of humanism, humans exhibit predictors within the learning environment (Daniels & Mthimunye, 2019). They will invest effort if they believe their inputs yield practical outcomes. Despite individuality, humanistic educational theory identifies predictive patterns among students (Daniels & Mthimunye, 2019). Implementing humanistic educational theory as a framework for meaningful learning experiences can help unlock the predictive code of academic success. The learning environment must incorporate elements that motivate students to achieve learning objectives, providing a framework for customizable and meaningful educational experiences. Adult learners can pursue what they deem valuable, independent of societal opinions (Purswell, 2019; Yang & Hsu, 2020). Humanistic educational theory advocates for the development of the whole learner, integrating emotional, social, and cognitive growth to derive meaning from the learning experience (Purswell, 2019).

Related Literature

Contributors to Academic Success

Though research has laid out many contributing factors to academic success, there is no uniform definition or descriptor (Goegan & Daniels, 2021). Defining academic success and its contributors is dependent upon the academic environment. Many researchers believe that academic success is a catch-all phrase for a conglomerate of ideas associating student success with learning outcomes and contributions to the workforce (Goegan & Daniels, 2021). Research does agree on two broad contributing factors to academic success - non-cognitive (academic mindset, academic perseverance, learning strategies, social skills, and academic behaviors), placing the responsibility of academic success on the student and cognitive factors (course content, curriculum delivery methods, and teaching methodologies and pedagogies), placing responsibility on knowledge facilitators (Tepper & Yourstone, 2018).

Cognitive Factors

Course Valuing and Academic Success. Course valuing refers to learning experiences that are valuable, meaningful, and influential (Gupte et al., 2021; Hatlevik & Hovdenak, 2020; Nehari & Bender, 1978; Nel, 2017). Valuing an experience involves how students think and feel before, during, and after interactions (Galloway & Bretz, 2015; Heddy et al., 2017). Meaningful learning integrates thinking, feeling, and acting, empowering commitment and responsibility (Galloway & Bretz, 2015). Students ultimately decide to engage based on their perceived value of the experience (Cooper, 2013; Purswell, 2019). This decision hinges on their thoughts about content and feelings about the experience (Galloway & Bretz, 2015), affecting how much they value the experience. Finding value in an experience motivates achievement despite challenges (Cooper, 2013; Purswell, 2019). The experience must be perceived as worthwhile to overcome difficulties, as this found value can help students cope and succeed despite content-related challenges (Tepper & Yourstone, 2018).

Content Learning and Academic Success. Content learning, or the cognitive domain, pertains to how students acquire knowledge from subject matter (Nehari & Bender, 1978). According to Ausubel's (1963) theory of meaningful learning and Novak's (1993) human constructivism, learning occurs when new knowledge connects with prior knowledge and applies to practical situations like employability skills (Gupte et al., 2021; Parte et al., 2018; Schneider & Preckel, 2017). Mastery of content is achieved when learners incorporate knowledge into their existing frameworks (Parte et al., 2018). Cognitive content focuses on knowledge, free from emotions and assumptions.

Non-cognitive Factors

Personal Learning and Academic Success. Personal learning, or the affective-personal domain, encompasses the attitudes and motivations necessary for achievement (Daniels & Mthimunye, 2019; Gupte et al., 2021; Nehari & Bender, 1978). Students who relate academic experiences to their everyday lives demonstrate personal learning (Heddy et al., 2017; Priniski et al., 2018; Schneider & Preckel, 2017). Academic success is likely when content is personally relevant (Priniski et al., 2018). Personal learning merges cognitive content with course valuing (Daniels & Mthimunye, 2019; Gupte et al., 2021; Nehari & Bender, 1978).

Students' perceptions of experiences can be skewed; however, fulfilling both academic and personal factors enhances engagement. When educators focus on personal relevance, cognitive content becomes more engaging (Galloway & Bretz, 2015; Gupte et al., 2021). Learners derive meaning from experiences that engage their interests (Maghiar et al., 2015; Nehari & Bender, 1978; Nel, 2017; Untari, 2016). Yang and Hsu (2020) found that integrating personal learning materials significantly affected academic success. Students need to see connections between their needs and realities (Hatlevik & Hovdenak, 2020; Sheldon & Kasser, 2001). Yang and Hsu (2020) noted that internal motivation stems from the practicality of courses. Success increases when course content is personally meaningful and practical (Hatlevik & Hovdenak, 2020; Sheldon & Kasser, 2001; Yang & Hsu, 2020).

Behavioral Learning and Academic Success. Behavioral learning is how the learner perceives the experiences as affecting relationships with others and interactions with course content (Nehari & Bender, 1978; Schneider & Preckel, 2017). Research indicates that positive behavioral patterns contribute to academic success, with students demonstrating these patterns showing greater persistence (Chen et al., 2018; Kassarnig et al., 2018). Student behaviors and attitudes toward the learning experience influence their motivation to succeed. Factors like class attendance and community building foster collaboration, impacting academic success. Kassarnig et al. (2018) showed that peer interactions correlated with greater community among peers leading to increased collaboration and information exchange, significantly impacting academic outcomes. Class attendance was also vital for fostering this community and enhancing behavioral learning. Behaviors, whether direct or indirect, significantly affect learning within the community (Cao et al., 2018; B. Chen et al., 2018; Kassarnig et al., 2018).

Kassarnig et al. (2018) noted that self-esteem and conscientiousness are key behavioral predictors of academic success, influencing both personal and community achievements. Cao et al. (2018) found that students exhibiting orderliness in their lives achieved greater academic success, as orderliness influenced their interactions and the behaviors of others. Students who value the curriculum display behavioral patterns, self-esteem, and conscientiousness conducive to achieving learning objectives (George-Williams et al., 2019). B. Chen et al. (2018) concluded that positive self-attitude and conscientiousness lead to higher achievements. If students perceive educational processes as unaligned with their motivations, their behaviors reflect this perception (B. Chen et al., 2018; Kassarnig et al., 2018). Overall, students' experiences shape their learning behaviors, university experience, community building, and academic achievements (Cao et al., 2018; George-Williams et al., 2019; Hatlevik & Hovdenak, 2020).

Summary

This literature review examined the foundational literature surrounding the various domains of the CVI (course value, content learning, personal learning, and behavioral learning) and their impact on academic success (end-of-course grade) (Maghiar et al., 2015; Sobral, 2004). According to the humanistic educational theory, the educational experience is successful if the student finds the experience valuable and meets a personal need (Nehari & Bender, 1978). After a thorough literature review as well as correlation with the theoretical framework, aeronautics education has not been an area of research in correlating the specific domains of the CVI with student academic success resulting in the need to add to the literature on how the specific CVI predictors affect aeronautical students' academic success.

Methodology

The purpose of this non-experimental, predictive correlational study was to examine the predictive relationship between the predictor variables (course valuing, content learning, personal learning, and behavioral learning) and the criterion variable (end-of-course grade) for undergraduate aeronautical degree-seeking students. The outcome of this study lies in its potential contribution to the predictive factors related to the personalization of course content based on the individualized student perceived value and meaningfulness of their educational experience. The following research question and null hypothesis guided this correlational study:

Research Question

RQ1: How accurately can end-of-course grade be predicted by the subscales of the Course Valuing Inventory for an undergraduate aeronautical student?

Null Hypothesis

$H_0$1: There will be no significant predictive relationship between the criterion variable (end-of-course grade) and the linear combination of predictor variables (course valuing, content learning, personal learning, and behavioral learning) for undergraduate aeronautical students, as measured by the Course Valuing Inventory (CVI).

A non-experimental, predictive correlational design was chosen because numerical values were statistically analyzed, variables were not manipulated, and variables were compared to determine a relationship (Creswell, 2015; Gall et al., 2007). The predictive correlational research design allowed the researcher to examine relationships between two or more variables and allowed the researcher to determine the strength and direction of the variables and any predictive ability. (Creswell, 2015).

The study used a convenience sample of 113 undergraduate aeronautical pilot degree seeking students from a large, regionally accredited, faith-based, non-profit, private university in the southeastern United States. The sample consisted of participants who were at least 18 years old, were undergraduate aeronautical pilot degree-seeking students, had taken a non-ground or non-flight course (courses not directly related to piloting) at the university the term before the administration of the survey, and were willing to share their end-of-course grade. The sample size was determined to be sufficient to detect a correlational coefficient of 0.3 with a significance level of 0.05 and a statistical power of 80% (Creswell, 2015).

The survey instrumentation used to collect the data was the Course Valuing Inventory (CVI). The CVI (Nehari & Bender, 1978) has been used in past research studies to determine if a student's perception of value in the learning experience influenced academic success (Lawless; 1982; Maghiar et. al., 2015; Sobral, 2004). In this research study, the CVI (Nehari & Bender, 1978), was utilized to measure the independent predictor variables (course valuing, content learning, personal learning, and behavioral learning). The CVI is a survey design that contains 40 questions, divided into four categories of predictor variables, with ten statements in each category (See Appendix A). When measuring the reliability (Cronbach's alpha) of the 4 categories independently, the reliability of the categories range between 0.77 and 0.92. Reliability values range from acceptable to excellent which indicates the CVI categories are reliable and consistent (Nehair & Bender, 1978). When measuring the reliability of the 4 categories dependent upon each other, the reliability range was wider, 0.54 to 0.93 (Nehari & Bender, 1978). These scores indicate intercorrelations between the categories and their effects on the learning experience; however, those intercorrelations are unique and may or may not be independent of each other. Participants had unlimited time to respond to the 40 statements using a 4-point Likert scale.

The end-of-course grade, the dependent criterion variable, was obtained by the end-of-course results after the course had ended and was provided by the participant at the time of participation. The end-of-course grade was assigned a numeric equivalency (A = 1; B = 2; C = 3; D = 4; F = 5), transforming it into a categorical variable (Creswell, 2015; Gall et al., 2007).

The study was conducted after Institutional Review Board (IRB) approval. Data was gathered through voluntary participation. All information that could identify the participants was protected during all data collection stages. Ethical considerations were ensured through the confidentiality and anonymity of the participants. Because this research study utilized an online survey, the survey results were stored securely in an online cloud-based database.

Findings

Background

The quantitative study sought to determine if the aeronautical student's perception of course value, cognitive content, affective-personal, and behavioral factors of courses not directly tied to piloting impacted the student's academic success as measured by the student's end-of-course grade. The findings present a data analysis, results, and a summary. The study examined humanistic educational theory to determine whether a relationship exists between the perceived value and meaningfulness of an experience and the investment made in it.

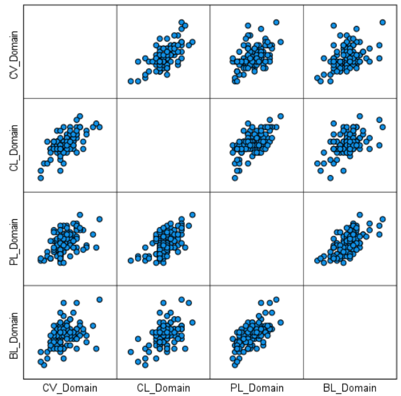
Data Analysis

Data Screening

The researcher sorted the data and scanned for missing data points and inconsistencies in each variable. No data errors or inconsistencies were identified. A matrix scatter plot was used to detect bivariate outliers between the predictor variables and the criterion variable. No bivariate outliners existed. See Figure 1.

Figure 1

Matrix Scatter Plot



Descriptive Statistics

Descriptive statistics were obtained on each of the variables. Participants' responses ranged from 1 to 4, where 1 represented strongly agree, 2 represented agree, 3 represented disagree, and 4 represented strongly disagree. The mean indicates the extent to which the participant evaluated the course as having been a meaningful, valuable, and significant learning experience. Table 2 provides the descriptive statistics for each variable.

Table 2

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
CV_Domain	113	1.60	3.40	2.3319	.32162
CL_Domain	113	1.40	3.10	2.3496	.27553
PL_Domain	113	1.40	3.60	2.2947	.48987
BL_Domain	113	1.50	3.50	2.4274	.34154
Valid N (listwise)	113				

Assumption Testing

The multiple regression requires the assumption of linearity and bivariate normal distribution be met. Linearity and bivariate normal distribution were examined using a scatter plot. Both assumptions were met. See Figure 1 for the matrix scatter plot. A Variance Inflation Factor (VIF) test was conducted to ensure the absence of multicollinearity. The absence of multicollinearity was met. Table 3 provides the collinearity statistics.

Table 3

Collinearity Statistics

Model		Collinearity Statistics	
		Tolerance	VIF
1	CV_Domain	.560	1.786
	CL_Domain	.462	2.163
	PL_Domain	.470	2.126
	BL_Domain	.550	1.818

a. Dependent Variable: Grade_Earned_Scale

Results

The results showed no significant relationship between the predictor variables and the criterion variable (F(4, 108) = 2.115, p = .084) (Nehari & Bender, 1978). The findings of this study verified the null hypothesis, meaning the study failed to reject the null hypothesis: The predictor variables are statistically independent of the criterion variable. Table 4 provides the regression model results.

Table 4

Regression Model Results

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.057	4	.514	2.115	.084[b]
	Residual	26.261	108	.243		
	Total	28.319	112			

a. Dependent Variable: Grade_Earned_Scale
b. Predictors: (Constant), BL_Domain, CV_Domain, PL_Domain, CL_Domain

The model's effect size was large where R = .270. Furthermore, R^2 = .073 indicating that approximately 7.3% of the variance of criterion variable can be explained by the linear combination of predictor variables. Table 5 provides a summary of the model.

Table 5

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.270[a]	.073	.038	.49311

a. Predictors: (Constant), BL_Domain, CV_Domain, PL_Domain, CL_Domain

Further Analysis

Because the null hypothesis could not be rejected, analysis of the coefficients was not required. However, evaluating the coefficients further, there is a negative correlation between course valuing domain and end-of-course grade. This means that as the end-of-course grade increased the meaningfulness of the experience, as measured by the course valuing domain, decreased (a downward slope of the linear relation). There is a positive correlation between end-of-course grade and content learning, personal learning, and behavioral learning. This means that as the end of course grade increased the meaningfulness of the experience, as measured by content learning, personal learning and behavioral learning domains, increased (upward slope of the linear relation). All coefficients had a relationship to end-of-course grade as each coefficient fell between 1 and -1. Even though there was a relationship, it is a notably weak relationship as each coefficient approached 0, meaning as the coefficient approaches 0 there is no relationship between the domain and end-of-course grade. Based on analyzing the domain coefficients further to determine which coefficient has the strongest relationship with end-of-course grade, it was found that personal learning had the highest relationship to end-of-course grade when compared with the coefficients of the other three domains. In addition, comparing the four domains with each other, personal learning domain was the best predictor of end of course grade because it had the strongest positive linear relationship at .258, greatest t score at 1.909, and the greatest probability where $p = .059$ (5.9%) which was the closest domain to $p < .05$ (5% likely). Table 6 provides the coefficients..

Table 6

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.523	.455		1.150	.253
	CV_Domain	-.017	.194	-.011	-.086	.931
	CL_Domain	.041	.249	.022	.165	.870
	PL_Domain	.265	.139	.258	1.909	.059
	BL_Domain	.007	.184	.004	.036	.971

a. Dependent Variable: Grade_Earned_Scale

Discussion

This study's results have practical and empirical implications, suggesting that the Course Valuing Inventory (CVI) survey tool can effectively measure student reflection on personal learning and the value they place on their learning experiences. To date, there are no other quantitative studies examining the predictive relationship between the criterion variable (end-of-course grade) and the linear combination of predictor variables (course valuing, content learning, personal learning, and behavioral learning) for undergraduate aeronautical students, as measured by the CVI. Because no quantitative study like this exists, no direct comparisons with previous research can be made. However, studies conducted in other disciplines associate the CVI's predictor variables with the criterion variable utilizing the CVI or an adaptation of the CVI.

In stark contrast to this study, the CVI was the best predictor of end-of-course grades among undergraduate medical students enrolled in Human Anatomy and Physiology courses (Sturges et al., 2012). Researchers Sturges et al. (2012) utilized the CVI survey to measure at-risk students to address and mediate performance in a Human Anatomy and Physiology course. Using the CVI in such a way, professors were able to target students and provide remedial measures to promote academic success. Sturges et al. (2012) spoke to the significant predictor power in utilizing the CVI to evaluate student perceptions regarding course value in meeting student needs.

This study supports humanistic educational theory, emphasizing the impacts of personal relevance and self-reflection in learning. Utilizing the CVI, research of Sobral (2004), Sturges et al. (2012), and Maghiar et al. (2015) found that there is a significant predictive correlation between the CVI's predictor variables and student reflection on personal learning and the value students place on that learning experience. The research concludes that the CVI is an accurate and valuable tool predicting a student’s quest for meaning, measuring the reflection and motivation of students, as well as gauging student interest. In agreement with this study’s findings, Sobral (2004) concluded that the CVI is an accurate tool for measuring the mindset towards learning rather than academic achievement measured by end-of-course grade. Similarly, and in agreement with this study, Sobral (2004) found unexpected relationships between predictor variables. In conclusion, the CVI is a significant tool supporting the humanistic educational theory when used to appraise the correlation between educational experience with self-reflection or self-regulation of the learner (Maghiar et al., 2015; Sobral, 2004; Sturges et al., 2012; Untari, 2016).

Limitations and Future Research

Limitations

Limitations included nonresponse bias, with the sample skewed toward students earning higher grades, which may not represent the entire population (Gall et al., 2007; Halbesleben & Whitman, 2013). The restrictive nature of the sample—limited to undergraduate aeronautical pilot focused students—also poses challenges for generalizability (Konig et al., 2021). The limitation of a non-neutral response within the Likert scale may have skewed the results requiring students to make a choice towards agree or disagree. Additionally, the correlational design restricts the ability to establish causation (Gall et al., 2007), and self-reported data may be affected by recall biases (Halbesleben & Whitman, 2013).

Future Research

This study sought to add to the existing literature on determining predictive variables and their contributions to end-of-course grade. At the time of this study, there currently exists no literature relating the predictability of the four CVI domains (course valuing, content learning, personal learning, and behavioral learning) to the criterion variable (end-of-course grade) for an undergraduate aeronautical degree-seeking student. However, this study unexpectedly found a predictive correlation between each of the four CVI domains (course valuing, content learning, personal learning, and behavioral learning). Consequently, and reflecting on the limitations presented, the following suggest a few areas for future research:

1. Since this study presented unexpected findings of internal validity between predictor variables, future studies should purposefully study how those four predictor variables relate to one another in various disciplines.
2. Future studies should broaden the sample population to determine if the CVI domains can predict an end-of-course grade. Gender, class standings, GPA, and other participant uniqueness' were not evaluated as part of this study. Future studies may consider adding and evaluating diversity in the participant population. In addition, future studies may consider evaluating how diversity contributes to the CVI's predictors and end-of-course grade.
3. Finally, determining if an end-of-course grade can be predicted by the subscales of the Course Valuing Inventory should expand to other disciplines. As in similar studies presented, some disciplines showed a predictive correlation between the CVI and an end-of-course grade. Future research should narrow down the causation of selected disciplines.

Conclusion

This study explored the predictive relationship between course valuing, cognitive content, affective-personal, and behavioral factors and undergraduate aeronautical students' end-of-course grades using the Course Valuing Inventory (CVI). Guided by humanistic educational theory, the study aimed to understand how students' perceptions of meaningful learning experiences correlate with their academic performance. Despite thorough analysis, the findings did not reveal a significant predictive relationship between the CVI domains and end-of-course grades. However, the study identified that personal learning exhibited the strongest, albeit weak, positive relationship with academic success among the predictor variables.

The findings contribute to the broader understanding of humanistic educational theory by emphasizing the value of personal reflection and relevance in the learning process. While the CVI proved to be a valuable tool for measuring student perceptions and reflections, its predictive power for academic outcomes in this specific context was limited. Limitations such as sample bias and self-reported data suggest that broader and more diverse research is necessary to refine the CVI's application across disciplines.

Future research should focus on exploring the interplay between the CVI domains, expanding participant demographics, and examining predictive relationships in different academic fields. By addressing these areas, future studies can deepen the understanding of how meaningful learning experiences influence academic success and contribute to the personalization of educational strategies, further advancing humanistic educational principles.

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APPENDIX A

Course Valuing Inventory*

Instructions: Please select only one scale rating from 1-4, one being strongly agree and four being strongly disagree, per statement to indicate the extent to which you evaluated last semester's course as having been a meaningful, valuable, and significant learning experience for yourself, and the extent to which you perceived the course as having had some impact upon yourself.

			Strongly Agree	Agree	Disagree	Strongly Disagree
	Domain	Question:	1	2	3	4
1.	CV	This course was a very valuable learning experience for me				
2.	PL	This learning experience helped me to become more aware of my own feelings and reactions				
3.	CV	I consider this learning experience as time and effort very well spent.				
R4.	PL	This course had no impact on my personal growth.				
5.	CL	The course helped me to acquire important basic knowledge.				
R6.	BL	This course had no impact on the ways in which I communicate.				
7.	CL	I can now relate to the subject matter of the course from a wider perspective.				
R8.	BL	In this course, I had not developed my own learning goals.				
9.	BL	Somehow I worked harder in this course than I usually do.				
R10.	CV	This was not a meaningful learning experience.				
R11.	CL	I did not gain much information in this course.				
12.	PL	This experience helped me to realize the importance of my own feelings.				
13.	CV	This course was a rewarding learning experience.				

14.	BL	This course was useful in helping me develop new ways of learning.				
15.	CL	I am aware of many significant experiences which resulted from taking this course.				
16.	CV	Overall, I would rate my experiences related to my enrollment in this course as positive.				
17.	PL	I feel more perceptive of others now, and more sensitive to their needs.				
R18.	CV	This was not an inspiring course.				
19.	BL	Somehow, I was more open and sharing in this course.				
20.	CL	I am now better able to conceptualize problems presented in this course.				
21.	PL	I understand better how others perceive me.				
22.	CV	This was a constructive and definitely helpful learning experience.				
R23.	BL	I participated in this course less than I .usually do.				
24.	PL	I have reflected upon what happened to me as a result of having participated in this course.				
25.	PL	In some ways, I feel good about myself due to this course.				
R26.	CL	My understanding of the subject matter of the course has not increased much.				
27.	BL	Somehow I have taken more risks in this course, and I feel good about it.				
28.	CV	I would like to take another course like this one.				
R29.	PL	This course had no impact on understanding of who I am or what I want.				
30.	CL	The course helped me achieve a deeper understanding of the field.				
R31.	BL	I did no more reading or thinking than was actually expected.				

R32.	CL	This course did not help me gain thorough knowledge of the field.				
33.	BL	I feel this course transformed me, enriched my life, and made me a more complete person.				
34.	PL	Some of my values have been clarified due to this learning experience.				
R35.	CV	I would not recommend this course to a friend.				
36.	CL	I have now a much clearer integrated notion of the subject matter of the course.				
37.	PL	I think I have learned to be more tolerant.				
R38.	CV	Taking the course made little difference to me.				
R39.	CL	I have not been able to tie things together and make much sense of the content presented.				
40.	BL	In this course, I have taken more responsibility for my own learning than I usually do.				

1 = Strongly Agree, 2 = Agree, 3 = Disagree, 4 = Strongly Disagree
R denotes reverse polarity
*Nehari, M., & Bender, H. (1978). Meaningfulness of a learning experience: A measure for educational outcomes in higher education. *Higher Education, 7*(1), 1-11. https://doi.org/10.1007/BF00129786

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Unveiling the Narrative Around Pilot Mental Health and Aviation - A Content Analysis of FAA and Mental Health-Related Social Media Content

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This study investigates the content on social media platforms surrounding pilot mental health and the Federal Aviation Administration (FAA) medical certification process. Utilizing Meltwater, a media monitoring and analysis tool, nearly 12,500 social media posts on platforms like Reddit and X (formerly Twitter) were analyzed to identify key themes and sentiments expressed by current and aspiring pilots. Findings reveal significant concerns about the FAA's mental health regulations, with many pilots expressing fear of career repercussions and reluctance to seek necessary mental health care. The study also highlights the importance of social media as a platform for pilots to anonymously voice their frustrations and seek support. The research ultimately advocates for enhanced FAA communication, education, and support resources that align with pilot needs and concerns, as well as encourages more open discussions about mental health within the aviation industry.

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Introduction

Becoming a pilot in the United States is rife with hurdles and challenges (Walden, 2025). One of the most difficult of these challenges is navigating the Federal Aviation Administration (FAA) Medical Certification process. Except in certain cases (sport pilots, etc.), pilots must have both their pilot certificate and their medical certificate on them when they fly (Medical Certificates: Requirements and Duration, 2024). In the civilian world, when would-be pilots begin the certification process, they are often told by the FAA, their flight instructors, and industry organizations, such as the Airplane Owners and Pilots Association (AOPA), to get their medical certificate as their first step even though it is not required until they solo an airplane (Airplane Owners and Pilots Association, 2024; Federal Aviation Administration, 2024a). However, flight instructors are not medical providers and are not always the most consistent and reliable source of information on how to complete FAA medical forms. Potential pilots often make mistakes or fail to understand the logic behind FAA medical forms in terms of mental health care and inadvertently - either rightly or wrongly - get denied or deferred a medical certificate.

Aviators have turned to anonymous social media platforms like Reddit, X (formerly Twitter), and others to reach sizable aviation communities with questions about the medical certification process, to air grievances and frustrations, share their personal experiences, and seek unofficial help that won't hinder their careers.

The purpose of this study is to examine the content and sentiment of social media posts made by potential and current pilots regarding the FAA medical certification process and pilot mental health. Possible emerging themes are investigated and identified from social media posts and then sentiment is assessed to determine emotional stance. By exploring this line of inquiry, the study provides a resource to those seeking greater awareness and highlights the broader implications of the current challenges faced by pilots concerning mental health. Finally, the study seeks to bring awareness to the public and the aviation industry about the unfolding narrative on social media in response to aviation mental health.

Aviation Medical Certification

Aviation and medical certification to fly airplanes have been inexorably linked almost since the beginning of powered flight in the United States. The Wright Brothers first flew the Wright Flyer in December 1903, and by June 1909, they sold copies of the aircraft to the US Army Signal Corps (Raines, 1996). This action tied civilian and military flying and their medical standards for the foreseeable future. According to the Air Services Medical Manual (1918), flying for the Signal Corps required pilot applicants who were already in the military to pass a more stringent physical fitness test to fly. The Surgeon General of the United States Army created a Chief Surgeon in the Aviation Section under the Signal Corps in 1917 to develop and implement more than 50 Physical Examining Units to qualify pilots and develop new physical qualification standards (pp. 41-42). While some prominent psychologists of the day took an interest in the burgeoning field of aviation, it was not until the demand for pilots and airplanes in 1940s World War 2 that anything other than physical aptitude was taken seriously (Jenkins, 1941). The echoes of an idealized military-style 'perfect specimen' medical certification process continue to ripple through the aviation industry.

Medical Certificates and Flying

Today, applicants in the United States pursuing most pilot certificates, including student pilot, private pilot, and commercial pilot, must seek and receive a medical certificate at least once from an Aviation Medical Examiner (AME) before being allowed to fly solo and ultimately receive their pilots' license (FAA, 2024a). The typical AME is, first and foremost, a physician operating their own private practice who medically reviews potential and current pilots as an adjunct to their primary practice. However, while acting as an AME, they are a representative of the FAA and follow the agency's proscriptive procedures and regulations. AMEs have found themselves at odds with their desire to medically help their patients and, at the same time, conform to the rules the FAA prescribes to AMEs (Crump, 2014).

First-time pilot applicants typically find themselves at an unfamiliar doctor's office to complete their medical paperwork and receive their examination. Anecdotally, many applicants show up to the AME with more questions than knowledge or background of the FAA and the medical process. However, once the applicant submits their paperwork, the AME is prohibited by the FAA from editing or helping applicants answer questions or ensuring the FAA accepts their medical history (FAA, 2024a). The FAA utilizes a website called MedXpress, and since 2012, applicants have been required to complete their medical history forms before they visit the AME (AOPA, 2012). Once a form is submitted in MedXpress and retrieved by the AME to begin the physical examination process, only three outcomes are possible: (1) Issuance of the Medical Certificate, (2) Denial, or (3) Deferral (i.e., sent to the FAA Office of Aerospace Medicine for further evaluation) (Aviation Medicine Advisory Service, 2024).

Applicants must divulge past medical history, including both physical and mental. Questions such as "Have you visited any health professionals within the last 3 years" is followed by statements that applicants are required to "enter ALL visits to any health professionals (such as physician, …. psychologists, psychiatrists, clinical social workers) for treatment, examination, or medical/mental evaluation." (FAA, 2024a).

The inclusion of psychologists and psychiatrists in the medical certification process is noteworthy. Mental health has become a less taboo subject in the general American psyche for the last 30 years (Pescosolido et al., 2021). Younger generations see prioritizing mental health as a triumph and not a setback (American Psychological Association, 2019). However, the FAA requires a complete history of MedXpress (FAA, 2024b). This means the FAA asks about and will know about any psychological treatment, no matter how acute, such as limited instances of therapy that could have resulted from bad breakups or domestic trauma. Even counseling sessions during collegiate years, a time filled with new physical, mental, and academic challenges for young adults, are required to be shared with the FAA, moreover, if the session was documented by an insurance provider.

Until 2023, a diagnosis of attention deficit disorder (ADD) or attention deficit hyperactivity disorder (ADHD) during adolescence was a reason to subject an applicant to an extensive and costly review even if the applicant had not ever taken medicine (Crump, 2023). For these reasons, pilots who currently hold medicals are very reluctant to talk publicly or identifiably about their own personal medical history or even talk privately to their personal physician for fear of a diagnosis that would prevent them from flying (DeHoff & Cusick, 2018). As Bor and Hubbard (2016) articulate, there is an "ever-present concern about the loss of license as a consequence of the onset of a disqualifying medical condition" (p.2).

Shifts in Openness towards Mental Health in Aviation

In 2015, the co-pilot of Germanwings Flight 9525 locked the door when the captain left the cockpit and initiated a descent, resulting in the loss of life for all souls on board (Bureau d'Enquetes, 2016). Subsequently, it was found that the co-pilot had episodes of severe depression years earlier and had recently seen multiple therapists and prescribed antidepressants, sleeping pills, and an antipsychotic drug (Kroll, 2016).

The Germanwings crash served as a critical event that began open conversations about pilot mental health (Pasha & Stokes, 2018). Even though the crash happened over the French Alps on a German airplane, pilots all over the world felt liberated to discuss specifics of mental health regulations with their own aviation agencies (Wu et al., 2016). These conversations moved from quiet, closed-door discussions between individuals to more open discussions on a variety of platforms, including public social media commentary and anonymous social media chats. Previously taboo for fear of reprisal, social media posts from would-be pilots and current pilots are now directed at the FAA's official social media accounts with satirical and quizzing content attempting to garner a response from the FAA on their mental health policies.

Insights Into Pilot Content and Sentiment on Social Media

Scholars have routinely used the content of social media messages to mine and measure public sentiment, mood, and opinions, such as for elections (Chauhan et al., 2021), public health emergencies like the COVID-19 pandemic (Chaudhry et al., 2021; Melton et al., 2021) and natural disaster recovery (Yan et al., 2020). Social media public perception studies measuring user understanding, interpretation, and impression, have also been conducted within the aviation industry to identify public perception of advanced aviation technologies like drones and air taxis (Tepylo et al., 2023) and to estimate the current state of the air transportation system (Monmousseau et al., 2021). Analyzing public sentiments, attitudes, and perceptions of future and current pilots about FAA medical certification involving mental health can lead to powerful insights that convey public opinion and assist in policy and regulation decision-making.

Anonymity on Social Media

Anonymity on social media in the form of hiding or disguising identifying information such as real name, age, or location can provide a shield for would-be and current pilots to express their grievances and frustrations about medical regulations without fear of reprisal from the watchful eye of the FAA. Anonymity allows a safe space for these individuals to communicate more freely, enabling them to disclose sensitive information or share negative sentiments that they might otherwise withhold in a more identifiable context (Pan et al., 2023).

This sense of invisibility has the potential to encourage more truthful and straightforward discussions as pilots feel less vulnerable to social risks, surveillance, and potential disciplinary action. Because pilots going through the medical certification process are hesitant to talk publicly about their medical history, the safety net of anonymity on social media has the potential to reduce social risks and fears of negative evaluation, making users feel more comfortable expressing their true thoughts and feelings.

Venting on Social Media

Social media serves as a modern forum for public venting, where users articulate personal and professional grievances that can influence both their social networks and broader public opinion. Previous research has identified top motives for sharing grievances to include altruism, i.e., efforts to prevent others from experiencing the same problem they encountered, resolution seeking, and expressing negative feelings (Whiting et al., 2019). Pilots, who perform highly specialized jobs and face significant stressors, are therefore likely to inform - albeit anonymously - their networks on social media about their own experiences with mental health conditions such as anxiety, depression, and ADD or ADHD, as well as offer advice to others to avoid negative impacts on an aviation career such as medical deferment or denial of pilot license. In terms of resolution seeking, they are likely to suggest reform to the medical evaluation process to avoid a culture of silence around mental health and ensure pilots do not forgo seeking treatment out of fear of losing clearance to work and fly. Additionally, they are likely to simply share their frustrations and negative feelings about the pressures of being a pilot and jumping through regulatory hoops (Rose, 2023; Sachs, 2023). Considering that individual negative emotions shared online have a higher likelihood of evolving into collective negative emotions shared by a larger group of people (Jalonen, 2014), this study aims to raise awareness among the public and the aviation industry about pilot negative content and sentiment shared on social media involving FAA medical certification and mental health.

Support Seeking on Social Media

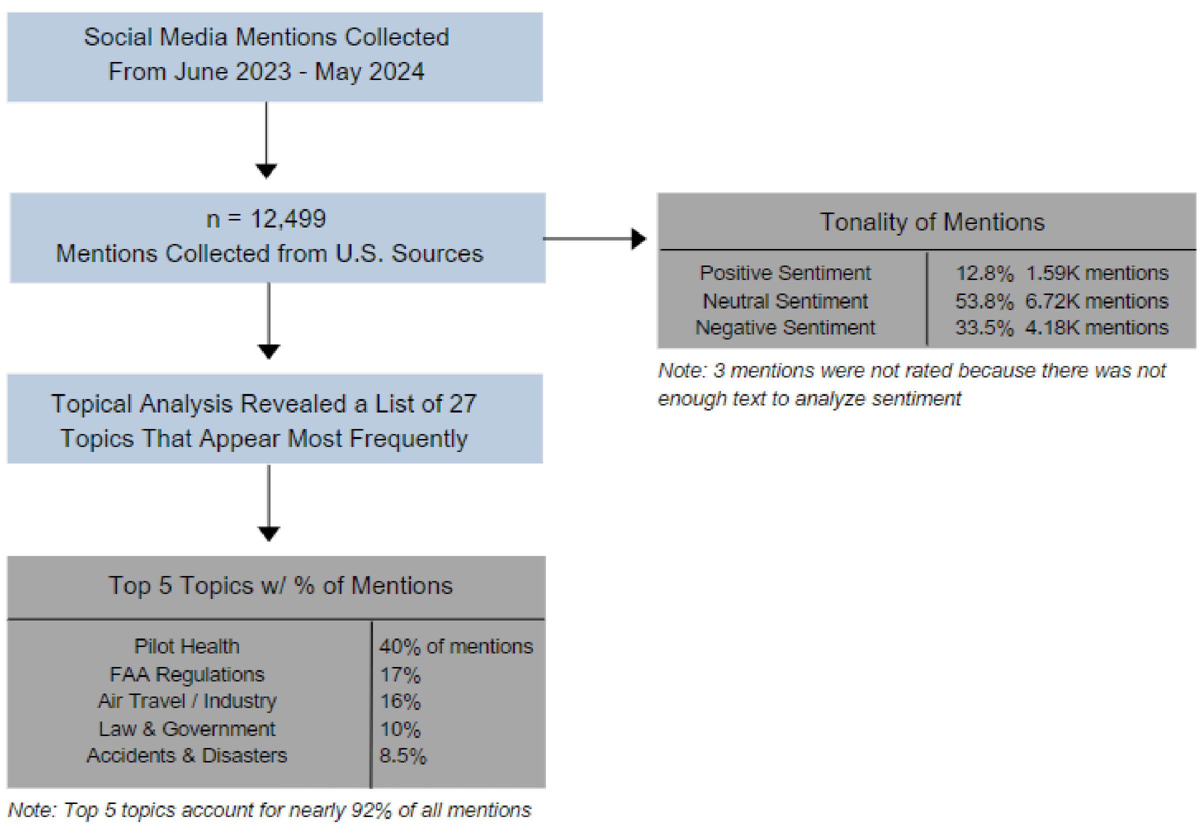
Social media platforms have become significant avenues for individuals seeking social support and connection and have been found to provide a venue for emotional catharsis, allowing users to share personal difficulties and seek support from their networks, which can offer a sense of validation and social connection (Kross et al., 2021). Additionally, social media support seeking oftentimes represents an important positive resource that promotes self-care behavior (Gilmour, 2019; Lin & Kishore, 2021) and can offset some of the adverse effects of negative life events (Nick et al., 2018). It is, therefore, not surprising that pilots, using anonymity, discuss topics like medical certifications, mental health challenges, and coping strategies on social media. These platforms provide a unique space where pilots can connect with others who understand the specific pressures and demands of the aviation industry. They can access peer advice and support for navigating the complexities of medical certification requirements, allowing them to feel less isolated, gain valuable insights, and build a supportive network that promotes both professional and personal well-being.

As would-be and current pilots continue to turn to social media platforms to publicly vent, seek support, and share experiences regarding FAA medical certification and mental health, this study aims to examine such content and categorize the discussions by topic and sentiment. More specifically, two research questions were generated: (1) What themes emerge on social media about FAA medical certification and pilot mental health, and (2) What is the overall sentiment or tonality of this content?

Methodology

This study provides a social media content analysis regarding the FAA's medical certification process and commercial pilot mental health. A sample of content was collected using Meltwater, a media monitoring and analysis platform, and search terms like "Federal Aviation Administration," "FAA," and "AME" were explored in combination with "mental health," "depression," "ADHD," and "anxiety." The timeframe of the search was between June 2023 and May 2024 and included data sources Reddit (n = 7.67K), X (n = 2.79K), blogs (n = 416), and forums or social message boards (n = 4.62K). A comprehensive analysis of keyword mentions was performed in Meltwater to identify topical themes and content sentiment. Data cleaning included removing all non-English and non-U.S. mentions to focus on U.S. aviation medical certification's impact on American pilots, resulting in a sample of 12,499 social media mentions. A flowchart is presented in Figure 1 for Topical Analysis and Sentiment.

Figure 1.
Flowchart for Topical Analysis and Sentiment



It is important to note that nearly 84% of mentions came from social media platforms Reddit and X. While this is only a window into the total social media narrative around the FAA mental health policy impact, it is an appropriate sample for the target industry and audience in this study. Approximately 93% of airline pilots are male (Hurst & Fry, 2023) and Reddit and X are more likely to be used by males compared to alternative social media platforms Facebook, Instagram, and TikTok that skew more female in usage (Pew Research Center, 2024).

Findings

The first research question sought to explore emergent themes or topics from social media about FAA medical certification and pilot mental health. Using Meltwater's natural language processing (NLP) algorithm, topical analysis identified 27 topics that appear most frequently in the data (n = 12,499). See Figure 1 The top five topics accounted for nearly 92% of all mentions: (1) pilot health, (2) FAA regulations, (3) air travel/travel industry, (4) law and government, and (5) accidents and disasters (Figure 1). Forty percent of mentions consisted of content about the FAA's guidelines for health and how they affect pilots. Seventeen percent of mentions consisted of content concerning FAA processes and regulations regarding medicals and mental health, including mention of the FAA establishing a Pilot Mental Health Aviation Rulemaking Committee (ARC) "to provide recommendations on breaking down the barriers that prevent pilots from reporting mental health issues to the agency" (Federal Aviation Administration, 2023, para. 1). Sixteen percent of mentions include content related to FAA medical certification impact on air travel and the aviation industry, 10% of mentions include content around military, state, and federal regulations and supports, and 8.5% of mentions include content about aviation industry accidents and disasters such as the Alaskan Airlines Flight 2059 in which a jumpseat passenger, who told police he was suffering from depression, attempted to shut down the engines midflight (Koenig & Rush, 2023).

Top Theme: Pilot Health

The pilot health theme accounted for such a large percentage of overall mentions; therefore, it was necessary to examine with deeper context, resulting in the identification of numerous sub-topics such as health conditions, mental health, medical specialists/facilities and services, medications, substance abuse, and health education. Seventy-three percent of sub-topic content was related to the FAA's stance on pilot mental health, concerns about the process of obtaining FAA medical clearance for individuals with anxiety, depression, and neurological conditions such as ADHD, and support-seeking and coping behaviors (Table 1).

Table 1.
Most Frequent Sub-Topics Within the Pilot Health Theme

Sub-Topic	percentage of theme mentions
Health conditions	**46%**
Top discourses within the health conditions sub-topic: ● Neurological conditions *(9.5% positive sentiment, 58.6% neutral, 32% negative sentiment)* *Top Keywords: medication, diagnosis* ● Sleep disorders *(3.1% positive sentiment, 69.2% neutral, 27.7% negative sentiment)* *Top Keywords: meds, doctor, sleep apnea* ● COVID-19 *(2.7% positive sentiment, 54.1% neutral, 43.2% negative sentiment)* *Top Keywords: acute covid*	
Mental health	**27%**
Top discourses within the mental health sub-topic: ● Anxiety and stress *(7% positive sentiment, 50.7% neutral, 42.3% negative sentiment)* *Top Keywords: anxiety, help meds, depression, medical review forms* ● Depression *(6.6% positive sentiment, 45.4% neutral, 48% negative sentiment)* *Top Keywords: depression, medication, antidepressants, medical certificate* ● Counseling Services *(10.4% positive sentiment, 73.8% neutral, 15.8% negative sentiment)* *Top Keywords: mental health, therapist, diagnosis, depression, anxiety, insurance*	

Health Conditions

Forty-six percent of posts within the pilot health theme mention the FAA's stance on (and handling of) pilot health conditions and pilot concerns about the process of obtaining an FAA medical clearance. For example, one social media user posted, "Sadly, if you are a commercial pilot, seeking almost any medical treatment is a huge risk due to the FAA's stringent policies, and it can ground you really quickly. Most pilots lie about their medical treatment, especially if it's psychological. Nothing like going into 100K of debt and a couple years of training to become an airline pilot just to lose your medical because you had depression due to the death of a family member, etc." Similarly, another social media user posted, "I wanted to be a pilot, but I had some health issues. Probably a good thing they turned me down because, with the direction my health is going, I'd have to keep my entire life a secret from the FAA."

Top discourses within the health conditions sub-topic include: (1) neurological conditions - such as ADHD - in which posts discuss the FAA's requirements for medical records, particularly regarding diagnosis and medication *(9.5% positive sentiment, 58.6% neutral, 32% negative sentiment); (2)* sleep disorders in which posts mention concerns about the impact of FAA policies on sleep routines and overall well-being of pilots *(3.1% positive sentiment, 69.2% neutral, 27.7% negative sentiment); (3)* COVID-19 in which posts mention concerns about the impact of Long Covid on pilot health *(2.7% positive sentiment, 54.1% neutral, 43.2% negative* *sentiment).* In the context of ADHD, one social media user shared, “Had to quit my ADHD meds for two years, they said. I made it a year in-- symptoms kept piling up, I couldn't maintain a workout routine, and life started to crumble as I had no support network... I gave in and went back on the meds, and now if I don't stop them again within a year, I'll be too old by the time that two-year period (restarted, of course) would be over.” Similarly, another user posted, “It's pretty bad if you are a pilot. Literally, just mentioning depression to the doctor can mean your career is over. No one on antidepressants, ADHD medication, or anything like that is allowed to fly; the FAA would prefer if you have any mental health treatment that you just not have a career anymore.”

Mental Health

Twenty-seven percent of posts within the pilot health theme mention issues related to mental health, specifically depression, and anxiety, and their impact on the FAA medical certification process. For example, one social media user posted, “There is a severe mental health crisis amongst pilots that is buried because the FAA will take your license if you try to seek help. So many middle-aged divorced captains on the brink of losing it have to figure it out on their own so they don’t risk losing the one thing that keeps them going. Happy flying!” Another social media user shared, “They have so many draconian rules and standards that they ultimately incentivize pilots to NEVER mention or seek help for any kind of mental disorder or anything - it is insane. Like everyone probably goes through a spell of depression or sadness at some point in their lives - but if you were "dumb" enough to actually seek help or treatment for it - then your flying career is very likely over…” One social media user even tapped into the complexity and chaos of the aviation and piloting landscape today, “I’m making calls to my Congresswoman this weekend to ask for support bringing some amendments to the FAA reauthorization to address this topic. Basically, every pilot out there today has had some form of anxiety from the pandemic, furloughs, crazy passengers, and off-the-job life. Seeing a therapist just to talk shouldn’t put a person’s medical condition into question at all.”

Top discourses within this sub-topic include: (1) anxiety and stress in which posts mention concerns and challenges faced by pilots who have been diagnosed with anxiety, including the possibility of being grounded or facing difficulties obtaining or retaining medical certifications *(7% positive sentiment, 50.7% neutral, 42.3% negative sentiment);* (2) depression in which posts mention the FAA has specific requirements for pilots with depression, including the need for a diagnosis, copies of therapy notes, and documentation and duration of treatment *(6.6% positive sentiment, 45.4% neutral, 48% negative sentiment);* (3) counseling services in which posts discuss the FAA’s therapy disclosure and antidepressant policies *(10.4% positive sentiment, 73.8% neutral, 15.8% negative sentiment).* In the context of depression, one social media user wrote, “The fact that pilots can’t have a history of depression at any time in their life according to the FAA... doesn’t matter if they get treated or not… that means a depressed person is a murderer.” Another social media user explained that they think the FAA has two options, “Continue to treat mental health in a way that leads to pilots avoiding care or 2) actually improve aviation by giving pilots real mental health care options that don’t jeopardize careers. We can see the former isn’t working. It’s time to fix the FAA.”

A word cloud was used to visualize the most prominent themes and keywords in the dataset, i.e., the more occurrences of the word, the larger it appears in the cloud (Figure 2). As expected, keywords related to the Meltwater Boolean search, such as “FAA,” “pilot,” mental health,” “depression,” and “anxiety,” were most frequent. However, the appearance of words like “advice” and “consultation” hint that pilots are exhibiting support-seeking and resource sharing behaviors on social media. These include questions about navigating the complexities of the medical certification process while maintaining privacy and confidentiality, sharing personal experiences, and offering suggestions to consult with a local AME or reach out to industry resource groups such as AOPA and the Experimental Aircraft Association (EAA) before submitting an official examination.

Figure 2.
Word Cloud of Top Keywords and Entities

Note: Word size in the cloud is dependent on the frequency of results. The more occurrences of the word, the larger it appears in the cloud.

Social Media Sentiment

The second research question sought to identify the overall sentiment, or tonality, of content on social media about FAA medical certification and pilot mental health. Sentiment was examined using Meltwater’s NLP algorithm and rated positive, neutral, or negative. Results indicate that overall, 12.8% of mentions were positive (n = 1.59K), 53.8% were neutral (n = 6.72K), and 33.5% of mentions were negative (n = 4.18K). Additionally, three mentions were not rated because there was not enough text to analyze sentiment.

Topics driving negative sentiment mention the FAA’s strict and outdated policies regarding mental health for conditions such as depression and anxiety, difficulties pilots experience in disclosing mental health issues and associated negative consequences such as losing their career, and personal stories and experiences related to pilot mental health. Overall, a recurring topic in posts with negative sentiment is one that describes the FAA’s lack of progress in modernizing mental health policies and the lack of addressing the stigma surrounding mental health. This is evident in Figure 3, where larger text such as “prohibitive mental health policies,” “medical issues,” “help,” and “medical process” indicate more frequency in the content. It is also important to note the negative sentiment and frequency of the keyword “federal crime,” indicating that while pilots are looking for ways to navigate the FAA medical process with a history of anxiety, depression, ADHD, etc., they understand the severity of lying to the FAA regarding mental health history. According to AOPA, falsification on a medical application is grounds for cancellation of pilot certificates and may void insurance (Browner, 2024). Topics driving positive sentiment focus on the FAA establishing a Mental Health Aviation Rulemaking Committee (ARC) that will provide recommendations to identify and break down barriers discouraging pilots from reporting mental health issues and seeking care.

Figure 3.
Keyword Sentiment

Note: This figure represents positive and negative keywords from mentions that appear most frequently. The larger the text, the more frequently the topic is discussed in social media content.

Conclusion

This study explores the ongoing social media discussion surrounding pilot mental health in relation to the FAA’s medical certification process. It focuses on platforms like Reddit and X, where both aspiring and current pilots discuss their experiences, frustrations, and concerns. Utilizing Meltwater, a media monitoring tool, nearly 12,500 pieces of content were analyzed to explore topics and sentiments expressed by pilots online. The analysis reveals that discussions on these platforms are often charged with negative sentiment, reflecting pilot concerns over the potential impact of mental health disclosures on their careers, including fears of medical certificate denial or cancellation.

A significant outcome of the study is the crucial role that social media plays in providing a space for pilots to express their frustrations and seek support while remaining anonymous. The anonymity afforded to users by platforms like Reddit and X allows pilots to speak freely about sensitive issues, such as mental health struggles, without fear of professional repercussions from the FAA. This has led to more open discussions about the mental health challenges faced by pilots and has brought attention to what pilots view as the punishing nature of current FAA regulations, which many feel discourage pilots from seeking necessary mental health care. Additionally, the study highlights how social media narratives can shape public opinion and influence policy discussions by providing a window into the pilot community's collective experiences and perceptions.

The research also suggests that while the FAA publicly emphasizes the importance of mental health and wellness for pilots - such as 2024 changes to its Guide for Aviation Medical Examiners allowing pilots to be treated with certain depression and anxiety medications and the establishment of the Pilot Mental Health Aviation Rulemaking Committee (FAA, 2023), there is a persistent gap between policy intentions and pilot experiences.

The findings indicate that while a portion of the social media content is neutral or even positive, a substantial amount reflects negative views towards FAA mental health policies and a lack of support and resources. This negativity is often centered on the lack of progress in modernizing mental health regulations and addressing the stigma associated with mental health issues. By examining these social media discussions, the study advocates enhanced FAA communication, education, and support mechanisms that are aligned with pilot needs and concerns as expressed in their social media content.

Limitations

The study’s limitations reflect areas for future potential research. First, the Meltwater dataset predominantly consists of mentions from Reddit and X (formerly Twitter), which, while valuable in targeting the aviation community, may not capture the full range of pilot sentiment and experiences. The user demographic of these platforms skews male and may not reflect the perspectives of female pilots or those who use other social media platforms. Second, the analysis focuses on U.S.-based social media mentions, limiting the generalizability of findings to non-international aviation communities, where regulatory contexts and attitudes toward mental health may differ. Additionally, while Meltwater’s natural language processing algorithm provides a robust tool for topical and sentiment analysis, there is the potential for oversimplification of complex emotional nuances in posts. Finally, the study’s observational nature indicates it cannot establish a causal relationship between FAA policies and pilot behavior. Further qualitative research, such as interviews or case studies, can provide rich insights into individual pilot experiences with mental health disclosure and FAA medical certification processes. Future quantitative research might explore sentiment scoring and predictive modeling by predicting the likelihood of certain aviation themes based on social media posts.

Implications

The implications of this research are broad and hold significance for the FAA, the aviation industry, mental health advocates, and social media communication research. Findings highlight the need for more transparent instructions and support for pilot applicants completing medical forms, especially in the area of mental health. Findings also illustrate the power of social media to act as a support mechanism for pilots seeking social connection and validation. Finally, the gap between pilot experiences shared on social media and real-life aviation policies indicates the need for increased strategic communication between the industry and regulators.

Future Directions

There has been a sea of change in aviation mental health. Researchers, clinicians, and news organizations are talking about mental health in aviation and aerospace. Pilots, however, are still concerned with their anonymity when it comes to the FAA, mental health, and their ability to fly. Future research should expand upon the findings of this study by exploring additional social media platforms and analyzing a broader range of online content to gain a more comprehensive understanding of the discourse surrounding pilot mental health and FAA medical certification. While this study focused primarily on anonymous platforms like Reddit and X, future studies could examine more publicly identifiable social media sites, such as Facebook, Instagram, LinkedIn, and TikTok, which might provide additional insights into how pilots discuss their experiences and concerns regarding mental health policies. Moreover, interviews with pilots could complement this study, offering a deeper understanding of individual and personal experiences. For example, future studies could examine how effective social media support networks are in providing relief or guidance to pilots facing mental health challenges and whether these interactions influence pilot decisions to seek professional help.

Further research could also investigate the potential impact of demographic factors, such as age, gender, and experience level, on pilot attitudes and behaviors regarding mental health disclosure and FAA medical certification. This could help identify specific groups within the aviation community that may feel uniquely vulnerable to the current regulations and may benefit from more targeted intervention strategies.

Lastly, future studies could focus on how recent FAA initiatives to support mental fitness are being received by the pilot community, especially on social media platforms where pilots often seek support, share experiences, and discuss their concerns anonymously. It would be valuable to examine whether pilots are aware of the FAA's efforts to promote mental fitness and how these efforts are influencing their willingness to seek help. Additionally, research could explore the types of support pilots find most helpful online. Understanding these dynamics and tracking changes in content and sentiment over time could inform the development of targeted communication strategies that effectively reach pilots, reduce stigma, and encourage a culture of openness and support around mental health.

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Bridging the Gap: Evaluating Skill Alignment Between Collegiate Aviation Management Programs and Industry Needs

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The aviation industry's dynamic nature demands skilled professionals equipped to navigate complex challenges. Aviation Management, a pivotal discipline encompassing areas such as operations, finance, and safety, plays a critical role in the industry's success. However, the lack of a standardized definition for Aviation Management complicates curriculum design and evaluation, potentially widening the gap between academic preparation and industry expectations. This study examines the alignment between the skills developed in collegiate Aviation Management programs and those required for entry-level industry roles, addressing both technical and interpersonal competencies. Using survey data from current undergraduate students and recent graduates, the study identifies significant disparities in technical skill preparation, particularly in data analytics, programming, and specialized software usage. While students perceive their programs as offering foundational knowledge and networking opportunities, graduates report that additional training beyond their undergraduate education is often necessary to meet industry demands. This research highlights the need for enhanced technical training, integration of industry-relevant tools, and the inclusion of advanced data literacy in curricula. Based on these findings, the study proposes a framework for refining Aviation Management education, offering actionable insights for educational institutions and industry stakeholders.

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Introduction

The aviation industry is a dynamic and multifaceted field requiring skilled professionals to navigate a wide array of complex challenges. While public perception often places focus on the industry's pilots, flight attendants, and maintenance crews, Aviation Management personnel play an equally pivotal role in the industry's success. This discipline encompasses network planning, revenue management, airport operations, airline finance, safety programs, and corporate fields crucial to sustaining the industry's growth. However, Aviation Management lacks a universally agreed-upon definition, posing challenges for educational institutions and industry partners striving to align curricula with industry needs. With collegiate aviation programs serving as the primary pipeline for preparing talent for the industry, the future success of the aviation industry will lie in the hands of newly trained college graduates. As global air travel is projected to double by 2040 (IATA, 2023), ensuring that these future graduates receive the requisite skills and competencies they need to succeed within the evolving industry is critical to the well-being of the entire aviation sector.

Aviation Management programs, first introduced in the U.S. in the 1920s, have evolved but still lack a standardized definition (Phillips, 2004; Lu & Gao, 2023), making curriculum efficacy evaluations an obscure and challenging process. Previous research highlights gaps between the skills taught in Aviation Management programs and skills viewed as important by industry leadership. Morton et al. (2001) and Phillips et al. (2006) found that while upper-level personnel report that recent graduates demonstrate technical proficiency, they often lack confidence, comprehensive industry knowledge, soft skills, and business acumen. More recent studies, such as Peksatici-yanıkoğlu (2019), emphasize that the observed skill gaps in Aviation Management curriculums exist globally but are limited in their applicability to the U.S. context. Additionally, the industry's shift toward digitization and advanced technologies is increasing digital literacy requirements industry-wide, further underscoring the need for a reassessment of Aviation Management education (European Commission, 2015, Bejakovic & Mrnjavac, 2020).

Motivated by the gap in existing literature, we aim to examine the alignment between the skills developed in collegiate Aviation Management programs and those required for success in the modern aviation industry. We also seek to define the core competencies of Aviation Management as a collegiate discipline and identify gaps in education that hinder industry readiness. This study addresses the following research questions:

1. What skills and competencies do students perceive to be taught within their university's Aviation Management program?
2. What are the critical skills and competencies required by the aviation industry for entry-level management positions?
3. Do the skills students perceive to be taught within their undergraduate Aviation Management curriculum match those reported by recent graduates within entry-level positions within the aviation industry? Has the shift toward technology and digitization impacted skill requirements?
4. From the survey responses, how do we define what an Aviation Management program should look like as a collegiate discipline?

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We anticipate this study will provide data-driven insights into the degree of alignment between Aviation Management education and industry skill expectations, as reported by current Aviation Management students and recent graduates in entry-level positions in aviation- a first. By identifying skill gaps and proposing a framework and definition for standardizing Aviation Management curricula, the research will potentially benefit educational institutions, industry stakeholders, and aspiring aviation professionals.

The paper is organized as follows: an introduction overviews the study's guiding questions, followed by a review of relevant literature. The methodology employed in this study is then outlined, and the following section presents the findings and analysis. After thoughtful analysis and discussion of the results, concluding remarks are offered, and recommendations for future studies are made. Appendices of all survey questionnaires and recruiting messages are also included at the end of the work.

Literature Review

This study attempts to address the gap in research on evaluating skill acquisition within undergraduate Aviation Management programs and its translation to workforce success. We have identified two primary literature research areas: curriculum research within Aviation Management (Area one) and curriculum research outside Aviation Management (Area two). Four research themes have been identified within Area one: Aviation Management skill acquisition studies, recent studies on Aviation Management curriculums, international research on Aviation Management curriculums/skill acquisition, and literature pertaining to defining Aviation Management. Within Area two, two research themes have been identified: curriculum studies within other aviation disciplines (such as Professional Flight and Unmanned Aerial Systems), and curriculum studies in industries outside aviation. These literature areas and their corresponding subthemes were identified during the review to effectively segment the literature review process. All areas were finalized and not altered after the completion of the review process.

Area 1 – Curriculum Research within Aviation Management

Aviation Management Skill Acquisition Studies

Research has explored skill acquisition in collegiate aviation programs previously, though much of it is outdated or incomplete. A 1998 survey of American Association of Airport Executives (AAAE) managers ranked "Management (general)" as the most crucial field of study for airport management but failed to evaluate student skill acquisition (Prather, 1998). Later, a study conducted by Morton et al. in 2001 (as cited in Worells, 2010) observed that while aviation programs provide foundational skills, graduates often struggle to apply problem-solving, project management, team building, and work analysis in early career stages. While the study does provide specific skills that entry-level personnel struggled to employ within professional settings, the data is now 23 years old and was not collected within the present conditions of the aviation industry.

Phillips et al. (2006) identified deficiencies in business principles and interpersonal skills among Aviation Management graduates, highlighting the value of internships but not analyzing

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the curricula that students were learning at the time. Similarly, Newcomer et al. (2014) noted a disconnect between educational experiences and industry needs, despite an increased preference for college degrees among employers, but does not detail specific aspects or learning areas where the disconnect is occurring. This study (2024) is the first since 2006 to examine both students and recent graduates, aiming to bridge gaps between academic preparation and professional expectations.

Recent Studies on Aviation Management Curriculums:

Recent publications provide insights into Aviation Management curricula but lack a direct focus on skill acquisition. Watkins et al. (2016) explore how the discipline-specific blend of education, certification, and experience (ECE) that industry managers possess influences the knowledge, skill, and abilities (KSAs) that they prefer to see in future employees. While the study does fill a gap in Aviation Management curriculum research literature, it does not detail what those specific desired skills are for each discipline and does not address previously identified gaps in student preparation. Mott et al. (2019) discussed competency-based curriculum models for future aviation education and does propose a compelling “Emerging”, “Developing”, and “Proficient” framework for acquiring skills in collegiate Aviation Management curriculums, but it does not detail what coursework or specific Aviation Management skills would correspond to these development levels, and if these skills were relevant to success within entry-level positions post-graduation. These studies highlight the need for targeted research on curriculum effectiveness in preparing students for industry demands.

International Research on Aviation Management Skill Acquisition and Curriculum Education:

International studies have expanded the scope of Aviation Management education research in more recent years, though it often focuses on specialized contexts. While examining University-Industry Collaborations (UICs) in Turkey, Peksatici-yanıkoğlu (2019) found a sharp mismatch between the student skills acquired in college programs and those that were most in demand by Turkish industry partners. Fanjoy and Gao (2009) analyzed aviation education in China but focused on pilot training more than managerial disciplines. In Europe, Pavel et al. (2020) proposed integrating the U.N. Sustainable Development Goals (SDGs) (2015) into Aviation Management coursework and did so at a Romanian university, but did not assess the SDG’s practical application in the industry. Along similar lines, a Ukrainian and Polish study highlighted the need to incorporate the Standards and Recommended Practices of ICAO into Aviation Management curriculums, but it did not detail whether generated solutions were made in partnership with industry, and if so, whether students were benefitting from their involvement within the respective projects (Isaienko et al., 2018).

Several publications before the COVID-19 pandemic highlight the need for international aviation programs to re-evaluate aviation curriculums to grapple with high unemployment rates, economic instability, and the industry's inability to place students within entry-level postgraduate positions within corporations. A 2016 publication by Lappas and Karousis focused on the fallout from a large-scale 2014 McKinsey survey performed within central Europe on the regions’ discrepancy between faculty/staff perception of student readiness and corporate perceptions of

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student readiness. The publication suggested new modes and focus areas for collegiate aviation programs to consider implementing, considering only one-third of European students and companies believe that students possess the skills needed to succeed within the industry upon graduation (Mourshed et al., 2014).

Despite valuable contributions, these studies provide limited insights into effective skill acquisition for Aviation Management students in global contexts.

Literature Pertaining to Defining Aviation Management:

Efforts to define Aviation Management remain inconsistent. Phillips (2004) noted the discipline's unclear identity, which is often viewed as secondary to Professional Flight programs. Even in the present-day U.S. aviation collegiate environment, there is little publication regarding attempts to define Aviation Management and no agreed-upon definition of the discipline- the same can be said for Aviation Management programs across the globe (Peksatici-yanıkoğlu, 2019, Lu & Gao, 2023)**.** While Earnhardt et al. (2014) highlighted a growing industry preference for degree-holding candidates, the paper does not provide how the definition of the discipline should evolve due to the observed paradigm shift. Internships have been emphasized as critical to defining program quality (Lindseth, 1996; Worrells, 2010), yet the implementation of work-based learning programs remains challenging. Kaps and Ruiz (1997) suggested frameworks for ideal curriculum but did so without linking them to industry-required skills.

The absence of a unified definition and clear curriculum standards underscores the need for further research into how Aviation Management programs can better align with industry needs in hopes of creating standards in the future.

Area 2 – Curriculum Research Outside Aviation Management
Curriculum Studies of Other Aviation Disciplines

The post COVID-19 pandemic travel recovery has caused staffing shortages, prompting aviation organizations to hire aggressively while exposing weaknesses in graduate preparedness. Post-pandemic publications in other aviation disciplines outside of Aviation Management addressed a "new normal" in aviation education, but few explored actionable curriculum reforms (Yiu et al., 2021). Emerging research highlights in flight training features technologies like Extended Reality (XR) for improving learning outcomes (Flores & Ziakkas, 2023), though further testing is needed (Ahram et al., 2023). The broader industry has also seen an emphasis on reshaping training methodologies and certifications to meet new demands for pilots (Bureau of Transportation Statistics [BTS], 2023). Studies in Australia and Malaysia emphasized partnerships between Professional Flight programs and national air carriers to create industry-centric curricula for pilots (Thatcher & Michaelides-Mateou, 2016, p. 83; Mohamad & Aboudahr, 2021).

Aviation fields have experienced significant advancements in technology that have catalyzed opportunities to reshape curriculum. Unmanned Aerial Systems (UAS) curricula now emphasize competency-based learning, safety protocols (Polack & Van Kampen, 2020; Lercel & Hupy, 2020), and data literacy (Zhang & Stewart, 2019). Maintenance and engineering programs

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are increasingly incorporating simulation tools (Bernard et al., 2021) and AI applications (Wang et al., 2016) while leveraging interactive classroom environments to enhance engagement (Shakour et al., 2019; Starr et al., 2024).

Curriculum Studies Outside Aviation:

Research in other disciplines offers valuable parallels for understanding skill acquisition and curriculum design. Lee and Cho (2023) emphasized the critical role of curricula in equipping students with industry-relevant knowledge and skills, highlighting the need for continuous improvement to meet evolving industry standards. Similarly, Lichtenstein et al. (2010) explored how engineering students balance gaining practical skills with educational enrichment, revealing a disconnect between academic preparation and industrial demands. Students often switch to business or other STEM programs to gain more marketable skills, suggesting that curriculum misalignment can be severe enough to drive post-graduation career pivots.

Studies in business education underscore the importance of critical thinking and practical skill development within curricula. Braun (2004) identified a gap between university teachings and industry expectations and proposed a structured approach to integrating critical thinking into business curricula.

Summary of Literature Reviews

After a thorough research review, a literature gap exists in comparing skills learned in present-day U.S. collegiate Aviation Management curricula to those needed in entry-level aviation workforce positions, despite similar studies being recently conducted abroad in the recent past. Domestic research has been completed on the topic previously, but not since 2006. Results also find that skill-based training, curricula, research, and partnerships continued to be more widely observed within Professional Flight and Aeronautical Engineering degrees as opposed to Aviation Management. This is likely attributed to both career pathways requiring federal certification before industry entry is permitted. Furthermore, this observed research gap could also be attributed to a continued lack of definition for what Aviation Management ought to be as a collegiate discipline.

Methodology

Survey Development

This study utilized a mixed-methods approach, employing an online survey to collect qualitative and quantitative data from two cohorts: current undergraduate Aviation Management students and recent graduates from Aviation Management students (within five years). The mixed-methods design allowed for cross-sectional data analysis while also providing an opportunity to collect sentiment behind responses by asking respondents to qualify their opinions on different areas of their education and experience. The survey included a mix of open-ended questions, multiple-choice, "select all that apply," and Likert-scale items to encourage detailed and accurate responses.

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In considering how to evaluate the skill acquisition of current undergraduate students and recent graduates, ascertaining qualitative survey results that lacked meaning was of concern. While there are many rudimentary competencies that can make someone skilled (such as logical thinking or problem-solving capabilities), these competencies are often qualitative and hard to measure. However, these competencies are typically utilized when working with a technical program, such as MS Excel, a programming language, or another similarly complex platform. With each program having a more pre-defined capability, skills can be more readily qualified within these applications and can translate into more meaningful survey results.

When building a questionnaire-based survey with open-ended questions, it is critical to write questions with the audience in mind. There are four main types of questions that can be asked within a proper questionnaire: attributes, attitudes, beliefs, and behaviors (Defense Technical Information Center [DTIC], 2005, p. 36). Surveys usually begin with attribute questions that collect basic demographics of the respondents, followed by attitude questions that ask respondents how they feel about certain aspects of the topic in question (DTIC, 2005, p.37). After these questions, the survey design should focus on the beliefs held by the respondent before closing by asking them about how their beliefs and attitudes have influenced their specific behaviors. Jolene Smyth discusses the importance of ordering the questions from general to specific so that respondents are less likely to summarize their previous responses (Smyth, 2016, p. 229). The team used separate surveying pages to aid respondents in separating specific aspects of their Aviation Management experience from their overall judgment of programs while following the attribute, attitude, belief, and behavior approach.

Employing simple visual design strategies can further assist the survey's effectiveness in revealing sentiments on experiences in education and industry. The team employed grouping, an approach within a tailored survey design developed by Dillman et al. (2014). Their research discusses how grouping specific questions on differing pages helps continuity in the respondent's survey experience, strengthening their retrieval for response (Dillman et al., 2014, p. 217). While multiple pages were used within the body of the current student and recent graduate surveys, each page was grouped to facilitate active recall during the survey response.

Additionally, to reduce the number of participants that would leave the survey without submitting, only the demographic questions were required. The effect this had on the samples is discussed in *Results* and *Future Study*.

Survey Distribution

Two surveys were assembled to evaluate if the current skills that Aviation Management students perceive to be learning within their undergraduate curriculums match those reported as essential to post-graduation success by recently graduated Aviation Management students. Both surveys were designed in cooperation with the Purdue University Institutional Review Board (IRB) and were approved for dissemination on 18 March 2024. Additionally, the team completed extensive methodological work before survey dissemination to ensure the maximum number of responses would be elicited from both survey populations. The survey was released on 28 March and remained open until survey closure on 17 April (20 days). To address challenges in reaching the target group of Aviation Management students and recent graduates of Aviation Management

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programs, the team devised an outreach plan to both university officials and personal networks (Lefever et al., 2007, p. 575). The team contacted 92 universities with an accredited four-year Aviation Management program on 3/28/2024 and 4/3/2024. After messaging campaigns on LinkedIn were completed and email messages were sent to 95 aviation colleges, a total survey population of n=89 was generated, with 59 respondents answering the undergraduate Aviation Management skill acquisition survey and 30 respondents completing the Aviation Management Recent Graduate survey. Of note, only five universities responded to our initial email confirming that they would share the survey with their student population by the closure of the survey, resembling a target university participation rate of 5.43%. However, the survey team knows that students who attended universities whose administrators did not respond to the survey distribution email still responded to the survey. While this data is still genuine, neither survey population is sizable enough to mitigate the self-selection (voluntary) response bias in this experimental design. According to Farrokhi and Mahmoudi-Hamidabad (2012), both surveys needed 60 respondents to eliminate the voluntary response bias from the study. Thus, the results of this survey should be viewed with caution.

Data Collection and Survey Content

The survey collected responses on various topics, including skill acquisition, academic experiences, and workplace relevance of skills obtained in college. Additionally, student respondents were asked about skill strength with a suite of technical platforms: Excel, SQL, R, Tableau, Python, Diio Mi, SABRE, ArcGIS, ProDIGIQ, and CH-Aviation. The list was compiled based on a literature review of prevalent technical applications being utilized within the aviation space along with researcher experience in the industry. Ratings on educational experience, relevance of education in the workplace, and proficiency in skills taught were collected on an ordinal scale. These are ranked with ten as the best outcome and one as the worst. The measure of central tendency used for the ordinal data collected is the median- it is not as sensitive to extremes and does not require characteristics on a numerical scale (Fink, 2003, pp. 39-42). To comply with IRB regulations, all survey questions were optional to give respondents the freedom to answer only questions they felt comfortable with answering. Thus, variance in respondent sample size was expected to be observed between questions. Due to this optional answering format, it was implied that respondents would submit their responses if their overall survey was submitted as incomplete. Data from incomplete survey responses were handled on a question-by-question basis. If a respondent elected to answer a question, the response would count toward the response sample size for the question. If the respondent did not choose to answer the question, the respondent would not be included in that question's sample size count.

After survey participants arrived at the landing page for the survey, they were directed to a brief screening questionnaire that would determine if they were eligible to take one of two surveys: the current Aviation Management survey or the recent Aviation Management graduate survey. Eligibility was determined based on the participant's occupation (student or recent or recent graduate) and recent graduate graduation year (2019 and later). For the full verbatim of the screening survey, see Appendix C.

Institutional Review Board (IRB) Application

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The study received a Category 2 review exemption (research that only includes interactions involving educational tests and survey procedures) through the Purdue University Human Research Protection Program (HRPP) and the Purdue University IRB (HRPP, 2020). In addition to proving that the survey was to be used for educational test purposes only, the research team also needed to provide documentation that would verify that the study design, methodology, and procedure would not induce bias and would also not induce unintentional harm to the human subjects who complete the survey (HRPP, 2018).

To avoid convenience sampling while contacting aviation universities, email communication to University Officials for survey distribution to undergraduate bodies was recommended by IRB. This allowed for the mitigation of convenience sampling and identical survey distribution within each Aviation Management institution contacted. While social media messaging channels were utilized to distribute the study, recipients of the message through these channels will not be incentivized to complete the survey in any way, placing the entirety of the burden of promotion of the study upon the researchers themselves (HRPP, 2014, p. 5).

Results

Sample Overview

The study collected responses from a total of 89 participants, including 59 current undergraduate Aviation Management students and 30 recent graduates. While the response rate of 5.43% is known for the university messaging, it is not possible to determine the response rate of students, as the population of current and former Aviation Management students cannot be accurately determined. Participants represented a range of academic classifications, with seniors comprising the largest group among undergraduates (39%). Most respondents were Aviation Management majors, with some also pursuing secondary majors such as Professional Flight or business-related fields. To protect student identity, the university of the respondent was not recorded. Thus, the ratio of student respondents from the university conducting the research (Purdue) to those not attending Purdue could not be calculated.

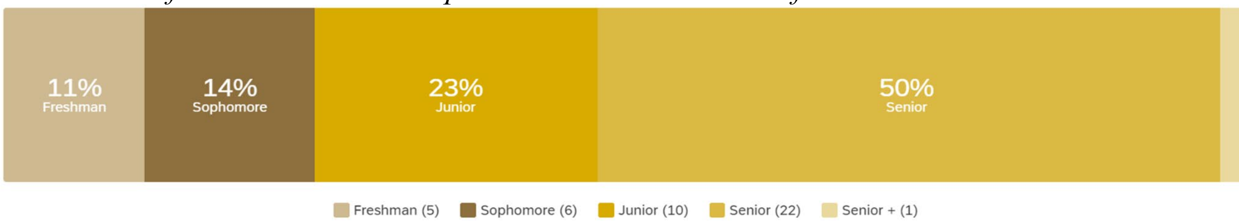
The full listing of survey questions that the Current Undergraduate and Recent Graduates sampling populations were asked can be found in Appendix A and B, respectively. Questions 1-4 on the Current Undergraduate survey, along with Questions 1-3 and 5 from the Recent Graduates survey, provided demographic information. As discussed in the methodology, all survey questions, except those for demographics, were optional.

Current Student Survey Results

The sample size for undergraduate students totaled 59 students. However, only 45 students completed the end of the survey, meaning 14 respondents entered but did not complete the survey. In terms of academic classification, there were five freshmen, six sophomores, 10 juniors, 23 seniors, and one 5th-year senior, see **Figure 1.**

Figure 1

Breakdown of Current Student Respondents' Academic Classification



Question 5: In your own words, how would you define Aviation Management?(open-ended)

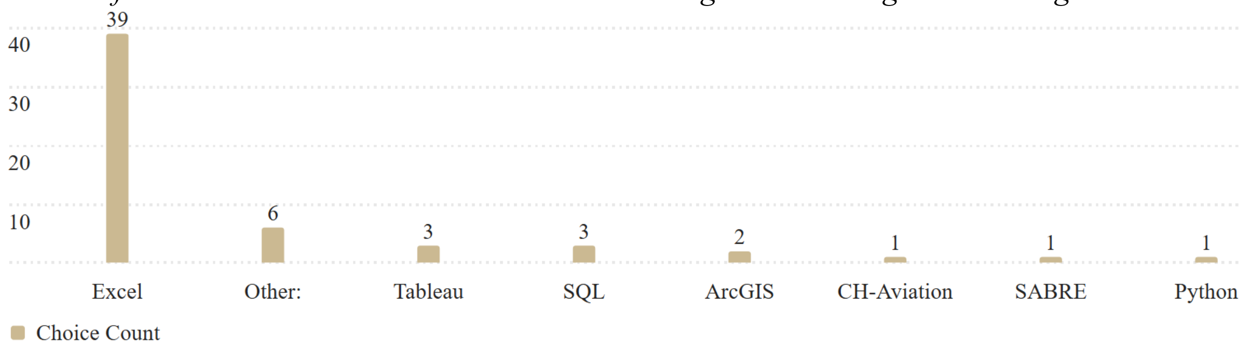
Students described Aviation Management as the "business" side of the aviation industry, frequently using terms like leadership, operations, finance, and regulations. Responses were notably detailed, reflecting students' ongoing exploration of the field. One student highlighted the breadth of the field, including areas like "finance, operations, regulations, strategies, airport knowledge, airline knowledge, and economic knowledge."

Question 6: What technical applications/platforms have you used within your Aviation Management program? (Not including internship/work experience) (options listed: Excel, SQL, R, Tableau, Python, Diio Mi, SABRE, ArcGIS, ProDIGIQ, CH-Aviation, Other:)

Microsoft Excel emerged as the most widely used application (see *Figure 2)*, with 70% of respondents (n=41) indicating using it within their coursework. Advanced tools like SQL, Tableau, and ArcGIS were less commonly used, with only 14% of students reporting exposure. No students indicated using ProDIGIQ, R, and, notably, Diio Mi, despite its relevance among operators in aviation. All three were listed as options but were omitted from the bar chart due to zero responses being obtained from respondents.

Figure 2

Counts of Technical Skills Used Within Aviation Management Undergraduate Programs



Note. n = 59. "Diio Mi," "ProDIGIQ," and "R" were excluded since they had a choice count of 0.

Question 7: On a scale of 1-10, how comfortable do you feel with the skills you listed? (1 being not comfortable at all, 10 being extremely comfortable) (Options listed: dependent on respondent's selections in Question 6)

Respondents were asked to rate their comfort level for skills they selected in Question 6 (refer to *Figure 2* for choice counts). As seen in *Figure 3*, more students reported the highest comfort level with Excel, giving it a median rating of 8 out of 10. Other tools, such as Tableau

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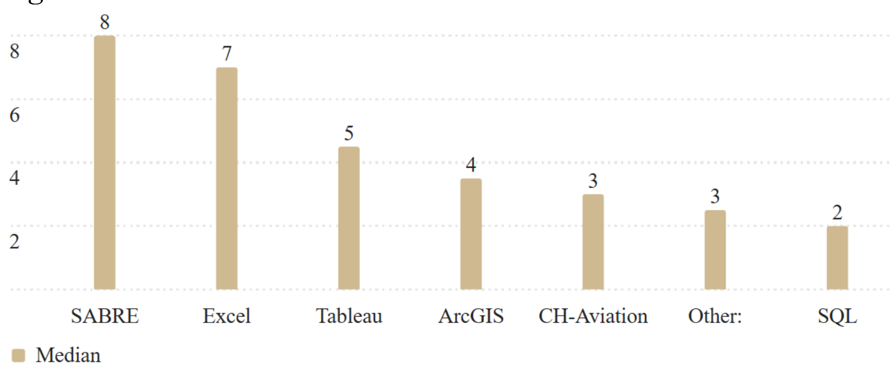
and SQL, received comfort ratings below 5, underscoring an extension of the exposure gap with technical proficiency beyond Excel as well.

Figure 3
Median Comfort Level for Students' Technical Skills Learned From Aviation Management Programs



Note. "Diio Mi," "ProDIGIQ," "Python," and "R" were excluded since they had a choice count of 0. While SABRE had the highest median, it only represents three students who reported using it (5% of the group that answered Question 6).

Question 8: Which of the following applications/platforms would you like to have included in your Aviation Management program? (Options listed: Excel, SQL, R, Tableau, Python, Diio Mi, SABRE, ArcGIS, ProDIGIQ, CH-Aviation, Other:))

The most requested additions to the curriculum were Python, Tableau, and SQL, each selected by more than 50% of the 27 respondents. SABRE, Excel, and ArcGIS followed closely, with over 33% wanting each, indicating a desire for greater emphasis on industry-specific software and advanced data analytics. Platforms like CH-Aviation, ProDIGIQ, and Diio Mi had 19%, 11%, and 4%, respectively.

Question 9: List 5 other skills not described in Questions #6 through #8 that you have learned from your Aviation Management program (free response).

24 students identified a mix of aviation-specific and broader skills. Commonly mentioned aviation topics included aviation law, safety management systems, and airline forecasting. Management skills such as leadership, project management, and networking were also frequently cited, along with business principles like finance, accounting, and market analysis. Data-related skills, such as forecasting and research, were highlighted as well.

Question 10: What skills taught outside your required Aviation Management coursework have you found to be beneficial during your college career? (free response)

Students noted several skills learned outside their core curriculum that were valuable, including leadership, data analytics (Python, SQL, Tableau), and communication skills. Many students credited second majors or extracurricular activities for these competencies, suggesting

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that aviation curriculums alone are not satisfying students' learning ambitions during their post-secondary experience.

Question 11: On a scale of 1-10, how satisfied are you with your educational experience within your school's Aviation Management curriculum (1 being the lowest, 10 being the highest)?

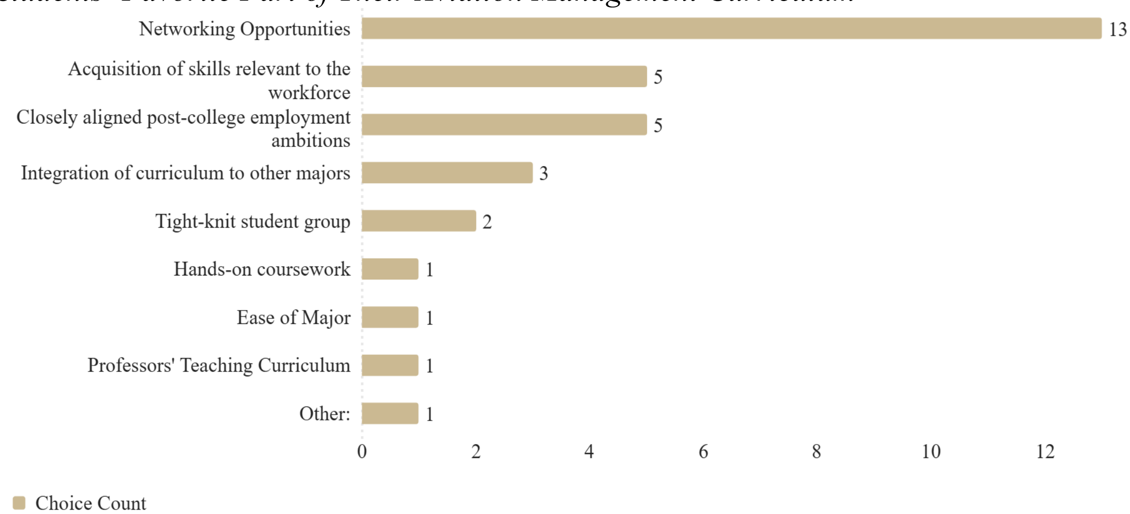
32 students rated their satisfaction with the curriculum at a median score of 7 out of 10, with a standard deviation of 2. The most common score was 8, reported by 12 students, indicating overall moderate satisfaction.

Question 12: What is your favorite part about the Aviation Management curriculum at your school? (Options listed: networking opportunities, closely aligned post-college employment ambitions, acquisition of skills relevant to workforce, Professors' teaching curriculum, ease of major, tight-knit student group, hands-on coursework, integration of curriculum to other majors, other:))

32 students responded to this question. Over a third of respondents chose networking opportunities as their favorite aspect of their respective aviation program (see *Figure 5)*. Combined with responses highlighting workforce readiness and career alignment, students valued the connections and applications their curriculum provided.

Figure 5

Students' Favorite Part of Their Aviation Management Curriculum



Note. The "Other:" response regarded appreciation for obtaining a business degree while also taking "classes relevant to the aviation industry."

Recent Graduates

For the purposes of this study, recent graduates were defined as any graduate of a four-year Aviation Management degree program in 2019 or later. The survey population for recent graduates totaled 14. It is important to note that five individuals who attempted to fill out the survey graduated with an Aviation Management degree before 2018, making them ineligible.

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These five people are not included in the count of 14 participants. Additionally, there were six survey participants who were eligible to take the survey but did not advance past the survey screening pages. Additionally, all 14 recent graduates filled out each question that was presented to them in the survey. Regarding major classification, all recent graduates indicated "aviation-management-related degrees" as their primary major. For secondary majors, three individuals stated that they received a second major. Those majors were "art and design," "airline operations," and "organizational leadership."

Question 4: In your own words, how would you define Aviation Management?(free response)

Recent graduates described Aviation Management similarly to current students but used noticeably more concise definitions that reflected their professional experience. A common theme was the combination of business management principles applied to aviation. For example, one respondent defined it as "business management focusing on aviation," while another emphasized its versatility as "the discipline of running and maintaining multiple aspects of aviation-related fields."

Question 5: Select any industry sectors in which you work, or have worked, within the aviation industry. If inclined, please note any company affiliations and job titles. (options listed: air carrier, airport, other aviation sector, outside of aviation)

All 14 respondents listed that they had current or previous industry experience in at least the air carrier, airport, or "other" industries within Aviation. Four respondents stated that they possessed more than one region of expertise. Specifically, the four survey participants stated that they possessed current or former industry experience in two of the above categories.

Question 6: On a scale of 1-10 [with one being the lowest and 10 the highest], how adequate do you believe the skills you obtained from your Aviation Management program are for your current and previous jobs within the industry?

Graduates rated the adequacy of their acquired skills at a median score of 7 out of 10. Scores ranged from 2 to 10, indicating a wide range in perceived preparedness. This suggests that while some graduates felt well-prepared, others noted gaps in their education relative to industry expectations.

Question 7: Name five skills you learned during your Aviation Management degree that you have used in your past or present roles within the industry (Not including internship/work experience during undergraduate education). (free response)

Graduates identified both hard and soft skills gained during their degree. Frequently mentioned skills included Excel, aviation terminology, teamwork, problem-solving, and specific industry knowledge such as FAR Part 139 compliance, NOTAMS, and ARFF. However, responses often characterized these skills as "basic," suggesting room for deeper curriculum development. Of note, first-response patterns were monitored for (a pattern or commonality in answers that were listed first could have indicated cross-industry importance), but none were found.

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Question 8: What skills or applications taught outside your required Aviation Management coursework during your undergraduate education have helped you to succeed in the industry today? (free response)

Graduates credited a variety of additional skills learned outside their required coursework toward their present success in the aviation industry, including communication, public speaking, and collaboration. On the technical side, skills like SQL, Tableau, and Python were commonly mentioned. Many graduates emphasized the importance of internships in developing both types of proficiencies. Interestingly, this grouping of valuable technical skills that recent graduates have learned outside of their post-secondary education aligns highly with the grouping of skills that current students seek to learn but do not receive within their Aviation Management training.

Question 9: What technical applications/platforms do you use today that you also used during your Aviation Management undergraduate program? (Options listed: Excel, SQL, R, Tableau, Python, Other:)

All respondents indicated continued use of Excel in their professional roles. Tableau was the second most used platform, with four respondents mentioning usage in both collegiate and professional settings. Tools like SQL and CAD were noted by a small number of respondents, while Python and R received no mentions, highlighting a potential gap in industry-relevant technical preparation.

Question 10: Outside of readily available applications/platforms, like the ones above, are there any specialized to the aviation industry you have used that you also had while enrolled within your Aviation Management program? (Options listed: Diio Mi, SABRE, ArcGIS, ProDIGIQ, CH-Aviation, Other:)

10 out of 14 (four left the question blank) graduates identified specialized aviation tools like Diio Mi, Sabre, ArcGIS, and Amadeus. Diio Mi and ArcGIS were the most frequently mentioned, with three respondents indicating they had used these tools both during their undergraduate studies and in their current roles.

Question 11: What skills or technical applications have you learned since joining the industry that you wish you had learned during your undergraduate Aviation Management program? (free response)

Graduates overwhelmingly emphasized the importance of SQL and advanced Excel skills, with each being mentioned by half of the respondents. Other skills, such as Tableau, Python, and industry-specific tools, were also highlighted. Responses pointed to a significant gap between the technical skills taught in students' respective undergraduate Aviation Management programs and those demanded by entry-level industry positions. The disparity between the recent graduate and current student responses is discussed and charted in the discussion section.

Questions 12 & 13: Evaluating recent graduates' workplace capability relative to peers and factors contributing to the rating. (1-10 rating, free response)

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Graduates rated their workplace capability compared to peers at a median score of 8 out of 10, one standard deviation above their curriculum satisfaction rating. Many attributed their confidence to niche aviation knowledge gained during their studies or prior experiences. However, gaps in technical skills, particularly in data analytics and programming, were frequently cited as a disadvantage compared to peers from non-aviation backgrounds. The notably higher capability rating relative to the median curriculum satisfaction score could also point to Aviation Management students "catching up" to their peers after graduating by learning technical tools and applications on their own time while in the workforce.

Discussion

In general, it should be noted how recruitment challenges, including limited university participation, low response rates, and low sample populations, highlight potential voluntary response bias within results (Farrokhi, 2012, p. 790).

Research Question 1: What do students perceive is being taught within their university's Aviation Management program?

Survey responses indicate that Aviation Management students perceive their program to focus primarily on basic technical skills like Excel, with some exposure to advanced tools such as SQL, Tableau, and ArcGIS. Key findings include:

- Current Student Question 6: 70% reported using Excel, but only 14.2% had access to advanced tools (SQL, Tableau, ArcGIS).
- Current Student Question 7: Of the 52% of the student population that reported being comfortable with Excel, their median rating of platform skill was 8/10. Notably, all other tools scored below 5/10.
- Current Student Question 8: Python, Tableau, SQL, and SABRE were the most requested technical programs to include in Aviation Management curriculums of the future.

Additionally, students report that their respective program gives them opportunities to cultivate soft skills and leverage the university's network to find professional post-graduation opportunities. Key findings include:

- Current Student Question 9: Non-technical skills gained included aviation fundamentals, law/regulations, safety management, leadership, project management, presentation skills, networking, and accounting/finance, with up to 11 students citing similar skills.
- Current Student Question 11: Curriculum satisfaction had a median rating of 7/10, with 8/10 being the most common, suggesting moderate satisfaction.
- Current Student Question 12: Networking opportunities and career-relevant skills were selected by students as their favorite aspects of being within their respective Aviation Management curriculum.

Overall, students perceive their programs as providing foundational aviation knowledge and management skills in an environment conducive to networking but lacking in advanced technical and programming skills, which are highly desired. Similar satisfaction ratings from current students and recent graduates (both obtaining a median score of 7/10) also suggest

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program stagnation since the late 2010s.

Research Question 2: What skills are required to succeed within current entry-level positions in the aviation industry?

Recent graduates surveyed identified Excel, Tableau, and SQL as essential technical skills, alongside critical interpersonal skills such as communication, leadership, public speaking, writing, and teamwork. These findings emphasize the need for both technical proficiency and strong interpersonal abilities in entry-level aviation roles. Also, a vast majority of recent graduates commented that the skills they learned within their undergraduate Aviation Management curriculum were “basic” compared to the skillset they employ to be successful within their present position. Key Findings Include:

- Recent Graduate Question 7: Alongside Excel and other technical programs, knowledge of federal aviation regulations was reported as a skill needed to succeed within the workplace.
- Recent Graduate Question 8: The grouping of technical skills that recent graduates have learned outside of their post-secondary education to be competitive within their respective workforce aligns highly with the grouping of skills that current students seek to learn but do not receive within their Aviation Management training.

Overall, recent graduates value their time in undergraduate programs but wish that more topic depth and technical skills could have been incorporated into the curriculum.

Research Question 3: Do the skills students perceive to be taught within their undergraduate Aviation Management curriculum match those reported by recent graduates within entry-level positions within the aviation industry? Has the shift toward technology and digitization impacted skill requirements?

The survey revealed a clear disconnect between the skills students perceive to be learning and the present technical skills recent graduates reported needing in entry-level aviation positions. Figure 6 groups the responses from current students (Currently Learning & Want to Learn) and recent graduates (Industry Demand). While students primarily learn basic technical skills like Excel, recent graduates described their current roles as requiring advanced tools such as Python, R, Tableau, SQL, SABRE, Diio, and Alteryx, with 62% of graduates indicating that the data analytics training in their programs was inadequate. A few reported services that airports use to maintain their Part 139 certification as well as airfield security. Many graduates reported learning these advanced skills only after entering the workforce or through courses outside their aviation curriculum. This resulted in more recent graduates commenting on why they did not feel as capable relative to their peers within these technical programs. Of note, while the student respondents did seek more soft skill development opportunities, the gap in soft skills reported by students and soft skills used in the workforce was significantly less than that of technical skills.

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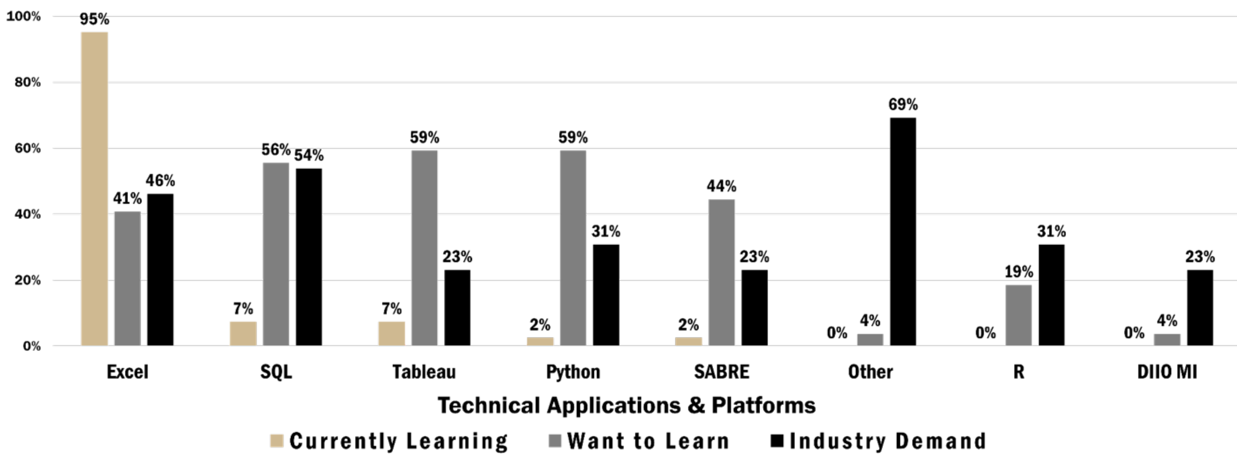
Figure 6
Comparison of Technical Skills Between Current Student and Recent Graduate Groups



Note. The number of responses for “Currently Learning,” “Want to Learn,” and “Industry Demand” were 41, 27, and 14, respectively. “Other” responses included CAD, AviPLAN, FAA’s Aviation Environmental Design Tool, & Amadeus.

Additionally, while dwarfed by concerns over technical skill readiness, recent graduates also commented on the vagueness of their Aviation Management college coursework- noting how specific aviation metrics were not covered in curriculums for the sake of breadth. Furthermore, federal regulations were undervalued by students but were identified by 38% of graduates as among the top five skills utilized within their professional roles. Teamwork emerged as a consistent focus across both student and graduate experiences, showing alignment in this area. Interestingly, the gap in skills that was observed within some aspects of recent graduates’ Aviation Management curriculum experience did not negatively impact the median satisfaction rating that graduated Aviation Management students gave, as their overall undergraduate experience was influenced by many factors beyond education. Overall, the findings highlight the need for Aviation Management programs to enhance technical training and incorporate more practical, industry-relevant coursework to bridge the gap between academia and industry expectations.

Research Question 4: From the survey responses, how do we define what an Aviation Management program should look like?

Given the qualitative data collection obtained by directly asking both survey populations, “In your own words, how would you define Aviation Management?” four characteristics of a possible definition for Aviation Management as a collegiate curriculum can be identified. Students and graduates consistently highlighted the importance of databases, data analytics, industry metrics, and critical business skills like finance and economics. These insights and consistent results suggest that a well-rounded Aviation Management curriculum should focus on four key elements:

1. Integration of business and management principles to oversee dynamic sectors like airlines, airports, and related entities.
2. Preparation for commercial, operational, and financial aspects of the aviation

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industry, ensuring efficient business operations while maintaining safety and regulatory compliance upon industry entry.
3. Development of data analytics skills to equip students for an evolving and data-driven industry.
4. Emphasis on soft skills such as leadership, teamwork, and communication, integrated into coursework.

While further research with larger populations is needed to validate these findings, the current data provides meaningful insight into designing curricula that prepare students to be successful leaders in the aviation industry.

Conclusions

The results of the surveys demonstrated a mismatch between the skills that current students perceive to be learning within their undergraduate Aviation Management curriculums and those that recent graduates report using within professional roles across the Aviation Industry. Most recent graduate respondents classified the information they learned within their undergraduate Aviation Management program as “basic” compared to the skillset they employ now. At a deeper level, these observed differences in depth also highlight an opportunity for Aviation Management programs to review and alter the theoretical foundation of the curriculum to ensure the theory delivered ensures appropriate skill delivery. While there was an observed rift in the importance of soft skills between current undergraduates and recent graduates (with professionals wishing they had more complete and developed soft skills), the most noticeable difference identified was within technical depth and breadth, contradicting previous studies. The technical abilities provided in undergraduate Aviation Management curricula were only a fraction of the diverse array of software and other technical platforms that recent graduates of Aviation Management programs listed as a skill that was important to their everyday success. Except for a few respondents, Excel was listed as the only technical skill they had been taught within their Aviation Management curriculum. Contrarily, most industry respondents listed numerous technical applications and software programs, such as advanced Excel techniques (such as Visual Basic and Macros), Python, SQL, Tableau, and SABRE, all of which they learned after completing their collegiate degree programs. Interestingly, this same group of technical programs and applications deemed critical to success by recent Aviation Management graduates were like those desired technical skills that Aviation Management undergraduate students want to learn within their undergraduate education. This was further echoed when “integration of hands-on/practical coursework” was the top response to how they believed their program could be improved.

It was also concluded that the lack of a formal definition for Aviation Management did not cause a difference in how current students and recent graduates defined the discipline, hinting that the absence of a formal definition was not the reason for the skill incongruity between Aviation Management students and recent graduates of an Aviation Management program.

The survey received fewer than 60 responses per group, falling short of the recommended threshold to mitigate voluntary response bias (Farrokhi & Mahmoudi-Hamidabad, 2012). To

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address this in future studies, the survey's availability period should be extended beyond the three-week window that was used in this study. Additionally, distributing the survey during less demanding academic periods, such as early or mid-semester rather than after spring break or near the end of the term, may improve participation rates. This timing adjustment could encourage both students and university representatives to engage more actively with the study.

The survey reached a limited and potentially non-representative sample, as only five of 92 contacted Aviation Management collegiate institutions confirmed survey distribution. Many responses likely came from Purdue-affiliated students, reflecting the researchers' proximity to the institution. Further hurting sample diversity, the survey could only be opened for three weeks due to the proximity of the end of the academic semester. Future studies should focus on establishing an outreach strategy for a longer timespan to enhance contact with Aviation Management programs nationwide, leveraging updated university directories and targeting specific contacts such as deans, professors, and administrative staff responsible for student communication. After adequate time has passed, ensuring distribution confirmation from these representatives will help verify broader participation and improve the representativeness of the data.

Survey completion rates dropped significantly after the initial questions, with many participants skipping open-response items or providing non-informative answers (e.g., "N/A"). To address this, future survey iterations should Reduce the number of open-ended questions and replace them with multiple-choice, Likert-scale, or "select all that apply" formats to enhance usability and engagement. Additionally, predefined answer options for complex questions (e.g., defining Aviation Management or listing skills) should be considered in future survey methodologies while ensuring the options are concise and relevant. These changes aim to shorten the time required to complete the survey, improve user experience, and increase participant retention.

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Appendix A: Survey Questions for Current Undergraduate Aviation Management Students

1. Academic Year Classification:
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Senior +
2. Primary Major:
    a. Professional Pilot-Related Degree
    b. Aviation Management-Related Degree
    c. Aeronautical Engineering/Technology/Maintenance-Related Degree
    d. Unmanned Aerial Systems-Related Degree
    e. Air Traffic Control-Related Degree
    f. Other: *Text Box*
3. Secondary Major (If applicable):
    a. *Same as #2*
4. Do you have internship/related work experience? Briefly describe your position.
    a. No
    b. Yes: Airline: *Text Box*
    c. Yes: Airport: *Text Box*
    d. Yes: Other Aviation Experience: *Text Box*
    e. Yes: Outside Aviation: *Text Box*
5. In your own words, how would you define Aviation Management?
    a. *Text Box*
6. What technical applications/platforms have you used within your Aviation Management program? (Not including internship/work experience)
    a. Excel
    b. SQL
    c. R
    d. Tableau
    e. Python
    f. Diio Mi
    g. SABRE
    h. ArcGIS
    i. ProDIGIQ
    j. CH-Aviation
    k. Other: *Text Box*
7. On a scale of 1-10, how comfortable do you feel with the skills you listed? (1 being not comfortable at all, 10 being extremely comfortable)
    a. *For each skill selected by the respondent in #6, an integer scale is displayed for the respondent to select their comfort rating*
8. Which of the following applications/platforms would you like to have included in your Aviation Management program?
    a. Excel
    b. SQL
    c. R
    d. Tableau
    e. Python
    f. Diio Mi
    g. SABRE
    h. ArcGIS
    i. ProDIGIQ
    j. CH-Aviation
    k. Other: *Text Box*
9. List 5 other skills not described in Questions #6 through #8 that you have learned from your Aviation Management program.

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    a. Skill (1-5): *Text Box*
10. What skills taught outside your required Aviation Management coursework have you found to be beneficial during your college career?
    a. *Text Box*
11. On a scale of 1-10, how satisfied are you with your educational experience within your school's Aviation Management curriculum? (1 being the lowest, 10 being the highest)
    a. *An integer scale is displayed for the respondent to select their satisfaction rating*
12. What is your favorite part about the aviation management curriculum at your school? (Pick One)
    a. Networking Opportunities
    b. Closely Aligned Post-College Employment Ambitions
    c. Acquisition Of Skills Relevant to Workforce
    d. Professors' Teaching Curriculum
    e. Ease Of Major
    f. Tight-Knit Student Group
    g. Hands-On Coursework
    h. Integration Of Curriculum to Other Majors
    i. Other: *Text Box*
13. What would you like to see differently (or improved) within the program? (Select all that apply)
    a. More Detailed Coursework
    b. Integration of Practical/Hands-On Coursework
    c. Higher Research Opportunities
    d. Better Networking Opportunities
    e. Major is too Hard
    f. Major is too Easy
    g. More Business-Focused Courses
    h. Other: *Text Box*

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Appendix B: Survey Questions for Recent Graduates in Aviation Management

1. In what 5-year time period did you graduate from your undergraduate Aviation Management program?
    a. 2018
    b. 2019
    c. 2020
    d. 2021
    e. 2022
    f. 2023
2. Primary Major While Attending?
    a. Professional Pilot-Related Degree
    b. Aviation Management-Related Degree
    c. Aeronautical Engineering/Technology/Maintenance-Related Degree
    d. Unmanned Aerial Systems-Related Degree
    e. Air Traffic Control-Related Degree
    f. Other: *Text Box*
3. Secondary Major While Attending (If applicable):
    a. Professional Pilot-Related Degree
    b. Aviation Management-Related Degree
    c. Aeronautical Engineering/Technology/Maintenance-Related Degree
    d. Unmanned Aerial Systems-Related Degree
    e. Air Traffic Control-Related Degree
    f. Other: *Text Box*
4. In your own words, how would you define Aviation Management?
    a. *Text Box*
5. Select any industry sectors in which you work, or have worked, within the aviation industry. If inclined, please note any company affiliations and job titles. *Note that any identifiable information will be de-identified*.
    a. Air Carrier: *Text Box*
    b. Airport: *Text Box*
    c. Other Aviation Sector: *Text Box*
    d. Outside of Aviation: *Text Box*
6. On a scale of 1-10, how adequate do you believe the skills you obtained from your aviation management program are for your current and previous jobs within the industry? (1 being not at all adequate, 10 being beyond adequate)
    a. *An integer scale is displayed for the respondent to select their adequacy rating*
7. Name 5 skills you learned during your Aviation Management degree that you have used in your past or present roles within the industry. (Not including internship/work experience during undergraduate education)
    a. Skill (1-5): *Text Box*
8. What skills or applications taught outside your required Aviation Management coursework during your undergraduate education have helped you to succeed in the industry today?
    a. *Text Box*
9. What technical applications/platforms do you use today that you **also used** during your Aviation Management undergraduate program? Select all that apply:
    a. Excel
    b. SQL
    c. R
    d. Tableau

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e. Python
f. Other: *Text Box*

10. Outside of readily available applications/platforms, like the ones above, are there any specialized to the aviation industry you have used that you **also had while enrolled** within your Aviation Management program?
    i. Diio Mi
    j. SABRE
    k. ArcGIS
    l. ProDIGIQ
    m. CH-Aviation
    n. Other: *Text Box*
11. What skills or technical applications have you learned since joining the industry that you wish you had learned during your undergraduate Aviation Management program?
    a. *Text Box*
12. Do you feel more or less capable than your coworkers that you have worked with during your professional career so far? Rate yourself on a scale of 1-10, with 1 corresponding to a feeling of low capability and 10 being a high capability compared to your peers.
    a. *An integer scale is displayed for the respondent to select their felt capability rating compared to their peers*
13. What contributed to your ranking against your peers?
    a. *Text Box*

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Appendix C: Screening Survey

1. Are you a current undergraduate student in an Aviation Management program at a collegiate institution?
    a. Yes: *Participant routed to Current Undergraduate Aviation Management Curriculum Skill Acquisition Survey*
    b. No: *Routed to Question 2*
2. Are you a recent graduate (5 years) of an Aviation Management program at a collegiate institution?
    a. Yes: *Participant routed to Recent Graduate Aviation Management Curriculum Skill Acquisition Survey*
    b. No: *Taken to Exit Screen*
3. Exit Screen: You are not eligible to participate in this survey. We thank you for your time.

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Contributing Factors to Aircraft Maintenance Technology Students' Readiness for the Aviation Industry

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The aviation sector demands highly skilled professionals, particularly in aircraft maintenance, to ensure safety and efficiency. Understanding the factors that affect the preparedness of the Bachelor of Science in Aircraft Maintenance Technology (BSAMT) students is crucial for academic institutions and industry stakeholders to enhance education and training programs. This study employs a survey research design to investigate the factors that contribute to readiness of BSAMT students for the aviation industry. The findings reveal that students have high confidence in their knowledge across critical areas, with positive feedback on the availability, maintenance, and completeness of training facilities. Additionally, students view the curriculum as well-designed, effectively meeting their educational needs and preparing them for a successful career in aviation. Co-curricular activities, including seminars, workshops, and on-the-job training, are perceived as the most influential in enhancing students' readiness. The study highlights the importance of integrating hands-on experiences with academic programs to ensure comprehensive skill development. The results suggest that a well-rounded curriculum, combined with strong industry engagement, is critical in preparing students for the aviation sector.

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Introduction

The aviation industry is one of the most dynamic and rapidly growing sectors globally. With increasing globalization and rising demand for air travel, the industry is expected to see continued growth in both passenger numbers and flight operations (Wensveen, 2023). As a result, there is an increasing demand for skilled professionals, particularly in the area of aircraft maintenance, which has become a crucial aspect of aviation operations. The need for highly skilled aircraft maintenance technicians is essential to meet the demands of a fast-evolving sector that relies heavily on technological advancements to ensure safety, efficiency, and sustainability (Ha et al., 2023; Mrusek & Douglas, 2020).

Aircraft maintenance plays a critical role in ensuring the safety, reliability, and efficiency of aviation operations. Proper maintenance procedures are vital for reducing risks associated with mechanical failures, which can have severe consequences for passengers, crew, and the airline. As noted by Singh et al. (2024), the primary responsibilities of aircraft maintenance technicians include inspecting, repairing, and maintaining aircraft in compliance with stringent safety regulations, such as those set by the Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA). These regulations ensure that maintenance practices meet the required standards for operational safety and airworthiness.

The role of aircraft maintenance technicians has become increasingly complex due to the sophistication of modern aircraft. Advances in avionics, materials, and propulsion systems demand that technicians be equipped with the latest knowledge and skills (Ha et al., 2023). In this regard, proper training and certification programs are essential to ensure that maintenance technicians remain up to date with the latest technologies and practices. Aircraft maintenance technology degree programs, such as those offered by universities and technical schools, are specifically designed to provide students with both the theoretical knowledge and practical skills necessary for successful careers in aircraft maintenance (Rañola, 2023). These programs focus on a range of topics, from aircraft systems and diagnostics to repair techniques and regulatory compliance.

In addition to technical skills, the role of maintenance technicians also involves a significant understanding of safety culture, quality assurance, and environmental considerations. Effective maintenance programs not only prevent mechanical failures but also minimize environmental impact by adhering to sustainability practices, such as the reduction of waste and emissions (Hauashdh et al., 2024). Furthermore, technicians must be able to respond to emergency situations and perform troubleshooting tasks in real-time, which highlights the need for ongoing professional development and adaptive expertise (Jiang et al., 2022).

With the rapid advancements in technology and the increasing complexity of aircraft systems, there is a growing demand for well-trained and competent aircraft maintenance technology program graduates. However, the transition from academic learning to actual employment in the aviation industry can be challenging for students. Despite the importance of this academic program, there exists a gap between the skills acquired by students and the expectations of the aviation industry; and this has to do with their readiness. Readiness in the aviation industry refers to the extent to which individuals possess the necessary skills, knowledge, and attributes to perform effectively in their roles (Kankaew, 2021). For aircraft maintenance technology students, readiness encompasses technical proficiency, regulatory compliance, problem-solving abilities, communication skills, and adaptability to new technologies.

The readiness of aircraft maintenance technology students for the aviation industry is crucial, given the growing demands of both local and international airlines. However, there is a lack of research on the factors influencing the readiness of Aircraft Maintenance Technology (AMT) students in developing countries like the Philippines.

Factors affecting this readiness are multi-faceted, ranging from technical skills to practical experience and personal attributes. Several studies have highlighted the importance of a strong educational foundation, industry-relevant training, and soft skills in preparing students for the challenges they will face upon entering the workforce. A critical issue is the ability of academic institutions to align their curricula with the constantly evolving needs of the aviation industry, especially given the rapid advancements in technology and regulations (Sun et al., 2021).

According to Cascio (2019), factors such as the quality of training programs, practical experience, technological advancements, and the evolving demands of the aviation sector are significant determinants of students' readiness for the industry. Moreover, the increasing complexity of aircraft systems, regulatory changes, and the rise of digital technologies in aviation require students to possess not only technical expertise but also critical thinking, problem-solving abilities, and adaptability (Keller et al., 2020; Zaharia et al., 2021; Thulasy et al., 2022).

In addition to technical competencies, the readiness of students is also influenced by the development of soft skills, including communication, teamwork, and critical thinking. According to Bennett (2015), effective communication and teamwork are essential in the aviation industry, as maintenance teams must often work under high-pressure situations. Without these skills, even the most technically proficient individuals may struggle in real-world scenarios (Alharasees et al., 2023). This highlights the need for a holistic approach to education that not only focuses on technical knowledge but also on interpersonal and problem-solving skills (Graesser et al., 2018).

Another important aspect to consider is the cultural and socio-economic factors that shape students' educational experiences. For example, access to advanced training resources, mentorship opportunities, and financial support may influence a student's ability to develop the necessary competencies for the aviation industry (Miani et al., 2021; Ng, 2022). These factors may affect not only the students' preparedness but also their confidence in performing tasks under pressure, which is essential in the high-stakes environment of aviation maintenance.

While studies exist on student preparedness in technical fields, few focus specifically on AMT programs in the context of growing aviation sectors. This study aims to address this gap by examining how curriculum design, co-curricular activities, training facilities, and theoretical knowledge impact AMT students' readiness for the aviation workforce in the Philippines. As the country's aviation sector expands, it is essential to align educational programs with industry needs to ensure the development of competent graduates. The findings will offer valuable insights for academic institutions, industry stakeholders, and policymakers on improving AMT education and enhancing graduate employability, contributing to the growth and safety of the aviation industry in the Philippines.

This study is also significant in advancing several Sustainable Development Goals (SDGs), particularly SDG #4 (Quality Education), SDG #8 (Decent Work and Economic Growth), and SDG #9 (Industry, Innovation, and Infrastructure). By examining the alignment of academic programs with industry needs, this research can help improve the quality of education, ensuring that aircraft maintenance technology program graduates possess the technical skills, industry experience, and soft skills required for the workforce. This enhances employability, contributing to economic growth and the development of a skilled workforce for the aviation sector. Additionally, by promoting industry-academia partnerships and the integration of innovation in education, the study supports the creation of a more resilient, inclusive, and innovative aviation industry, driving sustainable industrial growth and infrastructure development in the Philippines. With this, the study sought answer to the research question: what are the contributing factors on the readiness of Bachelor of Science in Aircraft Maintenance Technology (BSAMT) students in the aviation industry?

Specifically, the study (i) determined the students' level of confidence in the area of knowledge; and (ii) assessed the students' perceptions of the facilities, curriculum, and co-curricular activities as contributing factors to their readiness for the aviation industry.

Theoretical Framework

This study is grounded in the following theories that explore how various factors influence students' preparedness for the workforce:

Kolb's Experiential Learning Theory (2014) emphasizes that learning is a process whereby knowledge is created through the transformation of experience. In the context of BSAMT students, this theory suggests that readiness for the aviation industry is largely determined by the students' ability to engage in hands-on, practical learning experiences, such as internships or simulated aircraft maintenance tasks.

Vygotsky's Constructivist Learning Theory (1978) highlights the role of social interaction and cultural context in the learning process. For BSAMT students, this theory implies that readiness is influenced not only by individual cognitive development but also by collaborative learning experiences, such as teamwork in maintenance tasks or peer-assisted learning in problem-solving scenarios. Students who are exposed to collaborative environments are likely to develop better communication and interpersonal skills, which are essential for success in the aviation industry.

Becker's Human Capital Theory (2009) posits that investment in education and training enhances individuals' skills and abilities, increasing their productivity and employability in the labour market. In this study, Human Capital Theory underscores the importance of providing BSAMT students with adequate training, exposure to cutting-edge technology, and relevant skills to meet the demands of the aviation industry. The theory suggests that the readiness of students to enter the workforce is directly linked to the quality and relevance of the education and training they receive.

Bandura's Social Cognitive Theory (1986) focuses on the interaction between individuals, their environment, and their behaviors. For BSAMT students, this theory suggests that their readiness is shaped by their self-efficacy beliefs (confidence in their ability to perform tasks), outcomes expectancies, and the social environment they are exposed to. Students who have access to mentorship, industry exposure, and positive role models within the aviation industry are more likely to develop a strong sense of self-efficacy, which contributes to their overall preparedness.

Together, these theories offer a comprehensive understanding of how various factors, including practical training, collaborative learning, investment in education, and personal confidence, contribute to the readiness of BSAMT students to meet the demands of the aviation industry.

Materials and Methods

Research Design

This study employed survey research design to explore the factors affecting the readiness of Bachelor of Science in Aircraft Maintenance Technology Students in the aviation industry. Survey research design is a quantitative approach that collects data from a particular group of respondents to gain insights on various subjects. It generally involves distributing questionnaires or conducting interviews to obtain consistent information from a sample. This method facilitates the analysis of trends, relationships, and attitudes within a population (Creswell & Creswell, 2017). For this study, data was collected through face-to-face surveys.

Research Participants

A total of 140 participants took part in the survey. These respondents were purposefully chosen Bachelor of Science in Aircraft Maintenance Technology (BSAMT) students from a State College in the Philippines. Among the participants, 122 (87%) were male, while 18 (13%) were female.

Instrumentation

The instrument used to assess the factors influencing the readiness of BSAMT students for the aviation industry was developed by the researcher after conducting a comprehensive literature review. The self-administered questionnaire contained 16 items, organized into four sections: five items related to knowledge areas, four concerning facilities, four focused on the curriculum, and three addressing co-curricular activities. Each item was rated on a four-point Likert scale, ranging from "low confidence" (1) to "very high confidence" (4), or from "strongly disagree" (1) to "strongly agree" (4).

To ensure the instrument's content validity, it was reviewed by a panel of subject matter experts in aviation education, curriculum development, and industry standards. These specialists, who possessed extensive experience in both academia and the aviation industry, provided valuable insights into the clarity, relevance, and comprehensiveness of the questionnaire. Their backgrounds included expertise in aviation training programs, industry certifications, and the pedagogical frameworks necessary for preparing students for the aviation workforce. Based on their feedback, the researcher made minor revisions to enhance the instrument's alignment with the study's objectives, ensuring that the questions accurately reflected the critical factors contributing to the students' readiness for the aviation industry. This process helped ensure that the instrument was both relevant and robust in capturing the key variables related to the preparedness of BSAMT students.

Ethical considerations were carefully addressed throughout the study, particularly in terms of informed consent. Prior to administering the survey, the researcher explained the study’s purpose to participants and emphasized that participation was voluntary. Respondents were informed of their right to withdraw at any time without consequence. To maintain confidentiality, each participant was assigned a unique code number, which replaced personal identifying information on the survey. This coding system allowed the researcher to match responses to individual surveys while preserving anonymity. Additionally, data analysis was presented in aggregate form, ensuring that no personally identifiable information was disclosed, thereby protecting the privacy and confidentiality of all respondents.

Data Analysis

The study uses descriptive statistics, such as frequencies, percentages, and means, to conduct a descriptive analysis of the survey data.

To analyze the data, responses from the self-administered questionnaire are assigned numerical values based on a four-point Likert scale, ranging from 1 ("low confidence" or "strongly disagree") to 4 ("very high confidence" or "strongly agree"). The scores are then categorized into four confidence levels: 1.00-1.75 represents "Slightly Confident" or Strongly Disagree, 1.76-2.50 indicates "Moderately Confident" or “Disagree”, 2.51-3.25 corresponds to "Highly Confident" or “Agree” and 3.26-4.00 signifies "Extremely Confident" or “Strongly Agree”. After assigning scores to each response, the data is analyzed by calculating how many responses fall into each confidence category, either by counting frequencies or calculating percentages. This method allows for a clear understanding of students' perceived readiness in various areas based on their confidence or agreement levels.

Results and Discussion

Students’ Level of Confidence in the Area of Knowledge

The results presented in Table 1 reveal that the BSMAT students exhibit a generally high level of confidence in various areas of knowledge relevant to their field. The mean scores for all five areas of knowledge fall within the "Highly Confident" range (2.51 - 3.25), suggesting that the students perceive themselves as adequately prepared in key aspects of their training.

The highest mean score of 2.86 was observed in the area of air law and airworthiness requirements, indicating a strong level of confidence among the students regarding their understanding of aviation regulations pertinent to aircraft maintenance. The mean score of 2.82 in natural science and aircraft general knowledge, including fundamental mathematics and principles of physics and chemistry, indicates a strong foundation in the basic sciences. With a mean score of 2.83, students expressed a high level of confidence in their understanding of aircraft engineering, including material characteristics, construction, and powerplant systems. Students demonstrated a mean score of 2.99 in their confidence regarding aircraft maintenance procedures, which is the highest among the areas measured. This suggests that students feel particularly prepared to perform tasks such as aircraft overhaul, inspection, and defect rectification. The mean score of 2.95 for human performance and limitations reflects a strong understanding of how human factors influence aviation maintenance. This area is critical for ensuring safety, as maintenance technicians must be aware of their physical and mental limitations during their work.

Table 1
Level of Confidence in the Area of Knowledge

Area of Knowledge	*f*				*Mean*	Verbal Interpretation
	4	3	2	1		
1. How confident are you that you can still recall the air law and airworthiness requirements such as rules and regulation relevant to an aviation maintenance technician (amt) licenser holder?	27	72	36	5	2.86	Highly Confident
2. How confident are you in your knowledge about natural science and aircraft general knowledge like basic mathematics; units of measurement; fundamental principles and theory of physics and chemistry applicable to aircraft maintenance?	18	81	40	1	2.82	Highly Confident
3. How confident are you with your learning in aircraft engineering? (that includes characteristics and applications of the materials of aircraft construction including principles of construction and functioning of aircraft structures, fastening techniques; powerplant and their associated system)	25	71	40	4	2.83	Highly Confident
4. How confident are you with your education in aircraft maintenance such as required to ensure the continuing airworthiness of an aircraft including methods and procedures for the overhaul, repair, inspection, replacement, modification or defect rectification of aircraft structures?	37	66	36	1	2.99	Highly Confident

5. How confident are you in human performance area, with performance and limitations relevant to the duties of an aviation maintenance license holder?	30	75	33	2	2.95	Highly Confident

Range: 1.00- 1.75- Slightly Confident; 1.76-2.50- Moderately Confident;
2.51-3.25-Highly Confident; 3.26-4.00- Extremely Confident

Novak et al. (2018) emphasize the importance of regulatory knowledge in the aviation industry. Familiarity with air law and regulations is critical, as these rules directly affect the safety and legality of aircraft maintenance procedures (Woodlock (2023). This is consistent with Gauthama et al. (2024), who highlight the importance of scientific knowledge in understanding the complex systems involved in aircraft maintenance. Proficiency in basic scientific principles ensures that students can effectively apply theoretical knowledge to practical maintenance tasks. This result mirrors the findings of Wang and Zimmermann (2021) who note that comprehensive knowledge of aircraft structures and systems is essential for aviation maintenance technicians to ensure the safety and reliability of aircraft. The strong performance in this area may indicate that the curriculum effectively covers the technical aspects of aircraft design and engineering. As Dionne (2019) argue, practical maintenance skills are crucial for aviation technicians, and this result suggests that students are confident in applying what they have learned in real-world scenarios (Güneş et al., 2020). This result is supported by Shanmugam and Paul Robert (2015), who emphasize the importance of human factors training to reduce errors and improve performance in the high-stakes environment of aviation maintenance.

Students' Perception of Facilities as Contributing Factor

Table 2 highlights the students' perceptions of various facilities that contribute to their learning experience in the BSAMT program. The results suggest that students generally agree that the facilities available to them positively influence their development of technical and communication skills, as well as their overall learning experience.

The availability of an aircraft cabin mock-up facility, with a mean score of 2.90, received an "Agree" rating from the students. This suggests that students feel that having access to a simulated aircraft cabin is beneficial for enhancing their technical skills. With a mean score of 2.62, respondents generally agree that the availability of a speech laboratory positively impacts their oral communication skills. The mean score of 2.88 for the maintenance of laboratory facilities indicates that students agree that well-maintained labs play an important role in improving their technical skills. Properly maintained facilities are critical for providing a safe and effective learning environment. With a mean score of 2.91, students expressed agreement that the completeness of laboratory equipment enhances their learning. This includes access to necessary tools and machinery for practical training, which is essential for developing the technical expertise required in aircraft maintenance

Table 2
Facilities as a Contributing Factor

Facilities	*f*				*Mean*	Verbal Interpretation
	4	3	2	1		
A. Availability of aircraft cabin mockup facility to enhance my technical skill	33	73	22	12	2.90	Agree
B. Availability of speech laboratory to enhance my oral communication.	28	67	30	15	2.62	Agree
C. Maintenance of laboratory facilities to improve skill of the students.	32	71	26	11	2.88	Agree
D. Completeness of the equipment of laboratory facilities for enhanced learning of the students	34	69	28	9	2.91	Agree

Range: 1.00- 1.75- Strongly Disagree; 1.76-2.50- Disagree; 2.51-3.25-Agree; 3.26-4.00- Strong Agree

According to Ng (2023), such facilities allow students to engage in hands-on learning, which is essential for mastering the practical skills required in aircraft maintenance. The use of mock-up facilities enables students to familiarize themselves with the layout, systems, and components of aircraft, providing valuable practice in a controlled environment (Hayashi & Gondo, 2024). This supports the findings in language learning and communication theory that argue the importance of practice spaces where students can focus on speaking skills. Rad and Roohani (2024*)* suggest that dedicated facilities, like speech laboratories, allow students to practice speaking in a low-stress environment, which can help improve fluency, pronunciation, and overall communication skills.

As Srivastava et al. (2020) point out, up-to-date and functional laboratory facilities ensure that students can gain hands-on experience with the same tools and equipment they will encounter in the workforce, helping bridge the gap between theory and practice (Fletcher Jr & Tyson, 2017). Hora (2019) suggests that having access to a full range of equipment in laboratory settings provides students with the opportunity to practice a variety of maintenance tasks, ensuring they are well-prepared for real-world scenarios.

Students' Perception of Curriculum as Contributing Factor

Table 3 presents the students' perceptions of the curriculum and its effectiveness in meeting educational goals and preparing them for careers in aircraft maintenance. All four aspects of the curriculum—key concepts, subject relevance, logical sequence, and integration of values—received mean scores that fall within the "Agree" range (2.51–3.25), suggesting that students generally believe the curriculum is well-structured and aligned with their educational needs.

Table 3
Curriculum as a Contributing Factor

Curriculum	*f*				*Mean*	Verbal Interpretation
	4	3	2	1		
A. Key concepts addressed the program objective and program learning outcome.	39	74	22	5	3.05	Agree
B. Alignment and relevance of subject.	32	83	18	7	3.00	Agree
C. Logical sequence of the subject.	30	78	24	8	2.92	Agree
D. Integration of values, national customs, culture and tradition to the curriculum.	41	63	31	5	3.00	Agree

Range: 1.00- 1.75- Strongly Disagree; 1.76-2.50- Disagree; 2.51-3.25-Agree; 3.26-4.00- Strong Agree

With a mean score of 3.05, students expressed agreement that the key concepts covered in the program are aligned with the program objectives and learning outcomes. This suggests that the curriculum effectively supports the overall goals of the program, ensuring that students acquire the knowledge and skills necessary for success in the field of aviation maintenance. The mean score of 3.00 for the alignment and relevance of subjects indicates that students agree the courses are pertinent to their education and career aspirations. The relevance of subjects is critical for keeping students engaged and motivated. With a mean score of 2.92, students agree that the subjects are presented in a logical sequence. This suggests that the curriculum is well-structured, with a coherent progression from one subject to the next, which is important for building foundational knowledge before advancing to more complex topics. The mean score of 3.02 for the integration of values, national customs, culture, and tradition into the curriculum indicates that students agree that these elements are appropriately incorporated. This aligns with the growing emphasis on culturally responsive teaching in higher education.

Cruz (2022) and Dela Cruz and Dela Cruz (2020) emphasize that clearly defined learning outcomes and objectives are essential for guiding curriculum development and ensuring that students are adequately prepared for their professional careers. Lappas and Kourousis (2016) argue that a relevant curriculum enhances students’ learning experiences and ensures they are equipped with up-to-date knowledge and skills needed in the rapidly evolving field of aviation. Darling-Hammond et al. (2020) highlight the importance of curriculum sequencing in promoting deep learning, as it allows students to understand the connections between different concepts and disciplines, enhancing their ability to apply knowledge in practical settings. Nopas and Kerdsomboon (2024) suggests that integrating cultural aspects into the curriculum helps students develop a more holistic understanding of the world and prepares them to work in diverse environments, which is particularly important in global industries like aviation.

Students’ Perception of Co-Curricular Activities as Contributing Factor

The results presented in Table 4 illustrate the students' perceptions of the co-curricular activities provided in the BSAMT program. All three aspects of co-curricular activities—seminars/workshops, on-the-job training, and educational tours—received mean scores that fall within the "Agree" range (2.51–3.25), indicating that students view these activities as important contributors to their learning experience.

Table 4
Co-curricular Activities as a Contributing Factor

Co-Curricular Activities	*f*				*Mean*	Verbal Interpretation
	4	3	2	1		
A. Conduct of seminars and workshop	53	57	27	3	3.14	Agree
B. On the job training relevant to Aircraft Maintenance Technology.	51	57	28	4	3.10	Agree
C. Conduct of educational tour for the BSAMT students to the Airline Industry.	46	54	32	8	2.98	Agree

Range: 1.00- 1.75- Strongly Disagree; 1.76-2.50- Disagree; 2.51-3.25-Agree; 3.26-4.00- Strong Agree

With a mean score of 3.14, students expressed agreement that the seminars and workshops conducted are beneficial for their learning. These activities allow students to interact with industry professionals, gain insights into current trends and best practices in the field, and develop critical soft skills. The mean score of 3.10 indicates that students believe on-the-job training is a valuable and relevant experience for their career development. The strong positive response from students suggests that the on-the-job training aligns well with their educational goals and enhances their technical skills. The mean score of 2.98 reflects students' agreement that educational tours to the airline industry contribute positively to their learning experience. These tours provide students with firsthand exposure to the operational environment of airlines and aircraft maintenance facilities.

Chakraborty and Tripathi (2024) highlight the value of seminars and workshops in providing students with opportunities to engage in continuous learning and stay updated with industry developments. The positive response from students suggests that these co-curricular activities enhance their preparedness for the aviation industry.

On-the-job training is critical in aviation education, as it provides students with hands-on experience in real-world settings (Hora, 2019). Peksatici and Ergun (2019) emphasize that internships or job placements are essential in bridging the gap between academic knowledge and practical application, particularly in highly technical fields like aircraft maintenance. According to Morrow (2018), such tours allow students to see the practical application of their studies in a professional setting, providing context and a broader understanding of the industry. This exposure helps students connect their theoretical knowledge to real-world practices, enhancing their readiness for the workforce (Swargiary, 2024).

Factors Affecting the Readiness of BSMAT Students

Table 5 presents the factors influencing the readiness of BSAMT students for the aviation industry. The results are based on the weighted mean scores for each factor, providing insight into how students perceive the elements that contribute to their preparedness. These factors are ranked from most to least influential.

With the highest weighted mean score of 3.07, co-curricular activities were ranked as the most influential factor affecting students' readiness. This suggests that students view these activities—such as seminars, workshops, on-the-job training, and educational tours—as highly beneficial in preparing them for their future careers. The curriculum received a weighted mean score of 2.99, ranking second in terms of importance. This indicates that students agree that the program's structure, content, and alignment with industry needs significantly contribute to their readiness for the aviation field. With a weighted mean score of 2.90, facilities were ranked third in importance. This suggests that students see the availability, maintenance, and completeness of laboratory and training facilities as important factors in their preparedness. Although important, the area of knowledge received the lowest weighted mean score of 2.61, ranking fourth. While this score still falls within the "Highly Confident" range, it suggests that students feel slightly less confident in their theoretical knowledge compared to the other factors**.** This may reflect the complex and diverse nature of the technical knowledge required in aircraft maintenance, as suggested by Gauthama et al. (2024). While students recognize the importance of knowledge in areas like air law, physics, and aircraft engineering, they may feel that practical experience and co-curricular activities better prepare them for the industry.

Table 5
Factors Affecting the Readiness of BSMAT Students

Factors	*Mean*	Verbal Interpretation	Rank
1. Area of knowledge	2.61	Highly Confident	4
2. Facilities	2.90	Agree	3
3. Curriculum	2.99	Agree	2
4. Co-curricular	3.07	Agree	1

The results align with the following theories, showing that hands-on, industry-related experiences are crucial for student readiness, with co-curricular activities being the most influential factor: Kolb's Experiential Learning Theory (2014) highlights the importance of hands-on experiences. Co-curricular activities, ranked highest in this study, provide concrete experiences and opportunities for students to engage in real-world learning, which is essential for effective preparedness. Vygotsky's Constructivist Learning Theory (1978) emphasizes social interaction and guidance. Co-curricular activities place students within their Zone of Proximal Development, where they benefit from mentorship and collaborative learning, enhancing their readiness for the industry. Becker's Human Capital Theory (2009) views education as an investment in skills that improve future employability. The high ranking of co-curricular activities suggests that practical, real-world training is seen as more valuable than theoretical knowledge in preparing students for the workforce. While Bandura's Social Cognitive Theory (1986**)** focuses on observational learning and self-efficacy. Co-curricular activities provide students with role models and opportunities to build confidence in their abilities, reinforcing their preparedness for the aviation industry.

Conclusion

The study investigates the factors that contribute to readiness of BSAMT students for the aviation industry. The findings reveal that the BSAMT students possess a high level of confidence in their knowledge across multiple critical areas. Their positive responses to the availability, maintenance, and completeness of the facilities indicate that these factors play a significant role in their learning experience. The provision of relevant, well-maintained, and complete facilities supports students in developing the practical skills necessary for success in the aviation maintenance field. The students' positive perceptions of the curriculum suggest that it is effectively designed to meet their educational needs and prepare them for a successful career in aircraft maintenance. The integration of key concepts, relevant subjects, logical sequencing, and cultural values supports both academic and professional development. The positive perceptions of the co-curricular activities suggest that they play a significant role in supporting students' academic and professional development. Seminars, workshops, on-the-job training, and educational tours are effective in complementing the formal curriculum and providing students with practical skills, industry exposure, and a deeper understanding of the aviation maintenance field.

Overall, the findings indicate that co-curricular activities are the most influential factor in preparing BSMAT students for the aviation industry, followed by the curriculum, facilities, and area of knowledge. The results underscore the importance of practical, hands-on experiences, as well as a well-structured and relevant academic program, in shaping students' readiness for the workforce. These findings align with the literature, which stresses the significance of combining theoretical learning with practical exposure to ensure comprehensive skill development for students in technical fields like aircraft maintenance. The scores across all areas may reflect a well-rounded curriculum that prepares students for the diverse demands of the aviation industry. However, further research could examine whether these levels of self-reported confidence translate into actual competencies in real-world settings. Further research could also examine how these perceptions correlate with actual performance in laboratory settings and career outcomes.

In conclusion, by leveraging these factors through curriculum enhancements, industry partnerships, and improved training opportunities, educational institutions can significantly contribute to producing graduates who are well-prepared to enter the workforce and play a vital role in the growth and safety of the aviation sector.

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A Theoretical Model to Understand Flight Instructors' Safety Behaviors in the United States: Through Personality Traits, Self-Efficacy, Risk Perception, and Safety Climate

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Safety is an important aspect for any organization or individual to be successful, and the field of aviation has no exceptions. A CFI is authorized to give training and endorsements required for student, private, commercial, and instrument pilot certificates. CFIs play a very critical role in the success of pilot-in-training students at flight schools (Osman et al., 2022). According to AOPA (2015), the two greatest risks in flight training are loss of control inflight (LOC) and midair collisions. Moreover, approximately 71% of the accidents in which a CFI was involved happened during takeoff/climb, low-altitude maneuvers, and Instrumental Meteorological Conditions (IMC). The probable cause of LOC and midair collisions was due to poor decision-making, bad judgment, and unsafe behaviors of the CFIs (AOPA, 2015). In psychological aviation research, various perspectives, such as those associated with social cognition and personality, have attempted to explain individual differences in risky behaviors and accident involvement (Ji et al., 2011). The purpose of the present study was to build a theoretical model that demonstrates the relationship between personality traits, self-efficacy, risk-perception, safety climate, and safety behaviors of CFIs. A literature review was conducted to identify the existing relationships between the target constructs used in the study and the safety behaviors among workers across various aviation and non-aviation work settings. Over 100 abstracts were reviewed for relevancy, and 43 articles published between 1990 and 2020 were selected for full review. Of the 43 articles selected, only 30 articles were thoroughly reviewed and used to extract information. The results indicated the proposed theoretical model: (a) CFIs' personality traits as measured by CFIs levels of Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness will directly influence their safety behaviors; (b) CFIs' self-efficacy and risk-perception named as affective domain variables will have a direct influence on their safety behaviors; (c) CFIs' safety climate will directly influence their safety behaviors; (d) CFIs' self-efficacy and risk-perception will mediate the relationship between CFIs' personality traits and safety behaviors; and (e) Flight school's safety climate, will moderate the relationship between CFIs' personality traits and their safety behaviors.

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Introduction

Safety is an important aspect for any organization or individual to be successful, and the field of aviation has no exceptions. According to the FAA, a certificated flight instructor (CFI) is a person who holds a current license issued by the FAA and is authorized to train student pilots to fly an aircraft. The roles and responsibilities of CFIs are found under the Electronic Code of Federal Regulation (Code of Federal Regulations, 2025). A CFI is authorized to give training and endorsements required for student, private, commercial, and instrument pilot certificates. CFIs play a very critical role in the success of pilot-in-training students at flight schools (Osman et al., 2022). Although, in the past two decades various advancements have taken place in the world of aviation to improve safety, there were 13, 297 flight accidents and incidents in which a CFI was involved over a 10-year period (2009-2018), in the United States (National Transportation Safety Board [NTSB], 2018). Given that the accident and fatality rates of instructional flying are very high, there is often a question in the minds of the prospective flight students: How safe is the flight training? According to the 27th Nall Report (Airline Owners Pilot Association [AOPA], 2015), the two greatest risks in flight training are loss of control inflight (LOC) and midair collisions. Moreover, approximately 71% of the accidents in which a certificated flight instructor (CFI) was involved happened during takeoff/climb, low-altitude maneuvers, and Instrumental Meteorological Conditions (IMC). The probable cause of LOC and midair collisions was due to poor decision-making, bad judgment, and unsafe behaviors of the CFIs (AOPA, 2015).

In psychological aviation research, various perspectives, such as those associated with social cognition and personality, have attempted to explain individual differences in risky behaviors and accident involvement (Ji et al., 2011). Studies have examined how factors such as attitude, perceived risk, safety climate, and self-efficacy influence safety behaviors (Hunter, 2002, 2006; O' Hare, 1990). In the past, various theoretical models such as Big Five Personality (1990), Bandura's Self-efficacy (1977), and Bandura's Reciprocating Model (1987) have been studied to understand the safety behaviors of individuals. CFIs accompany pilots-in-training during their training process and play a very crucial role in developing their flying proficiency. Understanding the safety behaviors of CFIs could help the flight schools to improve their training program so that each student could be provided with optimal flight learning experiences and the safest environment possible. The purpose of the present study was to build a theoretical model that demonstrates the relationship between personality traits, self-efficacy, risk-perception, safety climate, and safety behaviors of Federal Aviation Administration (FAA) - approved CFIs. The theoretical model is grounded in the Big Five Personality theory and Bandura's self-efficacy theory.

Background

Historically, the effects of personality on the safety outcomes have been reported across various workplace settings (Barrick et al., 2013; Barrick & Mount, 1991; Christian et al., 2009). Some studies have also reported personality as a predominant factor in pilots' performance and training (King, 2014; Mesarosova et al., 2018). Studies related to personality research in aviation have emphasized understanding pilots' unsafe behaviors through personality traits (Musson et al., 2004; Siem & Murray, 1994). According to Barrick and Mount (1991), personality dimensions of Conscientiousness and Openness were positively related to job performance, while Neuroticism, which is related to emotional (in)stability, was negatively related to performance in various jobs. Further, Siem and Murray (1994) found that personality traits were a significant indicator of pilots' training performance, with pilots high in Conscientiousness having higher training performance.

Researchers have also demonstrated that an individual's self-efficacy is a significant predictor of safety behaviors across various workplace settings (Adjekulm, 2017; Chen & Chen, 2012; Parasuraman et al., 1993; Parera et al., 2016; Prinzel, 2002; Graham & Weiner, 1995). Chen and Chen (2012) conducted a study to investigate the relationship between self-efficacy and airline pilots' safety behaviors. The findings suggested that as pilots perceived self-efficacy increased, their safety behaviors measured as safety participation and safety compliance also increased. In another study conducted by Li et al. (2018), it was found that pilots with higher self-efficacy are less likely to be involved in human errors and unsafe behaviors. In another study conducted by Adjekulm (2017), it was found that student pilots with a higher self-efficacy are more likely to project high levels of motivation, and eventually help them in being compliant to all the required safety behaviors put forth by the flight school. Past research has also shown significant relationships between the Big Five personality traits and an individual's self-efficacy (Djigic et al., 2014; Perera et al., 2016). In a study conducted by Perera et al. (2016), it was found that Extraversion, Conscientiousness, Agreeableness, and Openness were positively correlated to self-efficacy among teachers. In another study conducted by Djigic et al. (2014), it was found that individuals high in Conscientiousness and Openness were more likely to have a higher level of self-efficacy, whereas individuals high in Neuroticism had a lower level of self-efficacy.

According to Burns and Slovic (2012), risk is a part of everyday life that everyone takes while making a decision. Research in the fields of occupational health safety, workplace safety, and health psychology have found risk perception to have a significant effect on safety-related behaviors (Brewer et al., 2007; Christian et al., 2009; Kraut et al., 2011; Taylor & Snyder, 2017). Hunter (2006) found significant negative correlations between measures from the Risk Self-Perception Scale and previous hazardous events. Some studies have also found personality traits influencing risk perceptions, both in aviation and non-aviation contexts (Fyhri & Baker, 2012; Ji et al., 2018; Wang et al., 2016). Fyhri and Backer (2012) found that Neuroticism was negatively correlated with risk perception of an accident. Wang et al., (2016) found that, among the construction project managers (CPMs), Extraversion, Agreeableness, and Conscientiousness were related to risk propensity and risk perception. Wang et al. found that CPMs high in Extraversion, Agreeableness, and Conscientiousness had less propensity towards risk, and were more likely to perceive unsafe behaviors as high-risk behaviors. However, CPMs high in Neuroticism had high propensity towards risk and were more likely to perceive unsafe behaviors as low-risk behaviors.

According to Griffin and Neal (2000), a safety climate is an important antecedent of safety performance across various work settings (Griffin & Neal, 2000; Hofmann & Stetzer, 1996). Mearns and Flinn (1999) found that employees' risk perception, which influences safety behaviors, was influenced not only by the working conditions but also by the organizational safety climate. Studies in the past have also found that employees working in both aviation and non-aviation settings who perceived high levels of safety climate also projected positive safety behaviors (He et al., 2020; Kouabenan et al., 2015; Lu & Tsai, 2010). Similarly, in a study conducted by Chen and Chen (2012), it was found that Safety Management System (SMS) practices were a critical determinant that influenced pilots' safety behavior. Among their findings, Chen and Chen concluded that SMS practices directly affected pilots' safety behavior. According to Fernandez-Muniz et al. (2007), the practice of SMS not only reflects the organization's commitment to safety but is recognized as a critical ingredient in employees' perceptions about the importance of safety in their company. There has been a great deal of research conducted in the past to investigate the effects of personality traits on safety behaviors across various work settings. However, there is a dearth of research that examines the relationship between the personality traits of CFIs and their safety behaviors. Similarly, most of the studies in the past have investigated the individual effects of self-efficacy, risk perception, and safety climate on safety behaviors. Limited research has been conducted that examines the mediating and moderating effects that affective domain variables such as risk perception and self-efficacy and safety climate have on the relationship between personality traits and safety behaviors. As a result, the current effort's key significance will be to fill the gap by building a theoretical model that describes the direct and indirect relationships between CFIs' personality traits, self-efficacy, risk perception, flight school's safety climate, and CFIs' safety behaviors.

Theoretical Grounding

From the literature review, it is evident that there are three types of variables that could influence CFIs' safety behaviors: the personality of the individual, the affective domain attributes of the individual, and the environment surrounding the individual. Consistent with this viewpoint, this effort proposes a theoretical model of the relationships between CFIs' personality, self-efficacy, level of risk perception, safety climate, and safety behaviors, which is grounded in two cognitive-based theories: the Big Five personality model (1990) and Bandura's (1977) self-efficacy theory. According to Novikova (1993), the Big Five personality traits are one of the contemporary versions of factor models of personality developed in trait theory. "The Big Five personality traits are the most basic dimensions in the structure of human personality that determine the features of human thinking, feeling, and behavior" (Novikova, 1993, p.1). These personality attributes impact behaviors in a range of different ways and have been shown to influence work behaviors and safety behaviors (Barrick & Mount, 1991; Barrick et al., 2013; Bues et al., 2018). The affective domain represents an individual's emotions, feelings, and attitudes towards learning and behaviors (Hoque, 2016). According to Bandura (1977), self-efficacy refers to a person's perceptions and attitudes about their ability to do something. Self-efficacy beliefs may have a larger impact on an individual's actions, emotions, behaviors, and motivations than their actual skill level (Bandura, 1994).

Big Five Personality

Continuous and systematic efforts have been made by various researchers to organize the taxonomy of personality traits (Cattell, 1946; Digman, 1990; McDougall, 1932). The five-factor model (FFM) of personality, developed by Goldberg (1981), is a hierarchical organization of personality traits in terms of five dimensions: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. The FFM later became known as the Big Five personality model (McCrae & Costa, 1990) and has been used by numerous researchers as a framework to explore the influence of personality in relation to job performance (e.g., Barrick et al., 2013; Barrick & Mount, 1991; Beus et al., 2018; Salgado, 1997). The emergence of the Big Five personality model has been widely accepted (Digman, 1990; Goldberg, 1991), and the nature of each trait is summarized in Table 1.1.

Table 1.1
Big Five Personality Traits and Descriptions

Dimensions	Description
Neuroticism	Intensity and frequency of experienced negative emotions, sensitivity to negative aspects of environment
Extraversion	Amount of energy directed outwards to the external environment and need for external stimulation
Openness	Receptivity to a range of external and internal sources of information and new input
Agreeableness	Role a person adopts in relationships on a continuum from compassion to antagonism; likelihood of person taking on board, accepting, and being influenced by perspectives or concerns of others
Conscientiousness	Strength of purpose and drive to goal accomplishment

Note. Adapted from Costa, T., & McCrae, R. (1992). Normal personality assessment in clinical practice: The NEO Personality Inventory. *Psychological Assessment*, *4*(1), 5.

According to the Big Five personality model (McCrae & Costa, 1990), the people who score high in Openness (also called Openness to Experience, Culture, or Intellect) are usually artistic, curious, imaginative, and original; and have broad interests, sensitivity to aesthetic experiences and fantasy, and a rich emotional life. In the context of the current theoretical model, high levels of Openness may influence CFI to explore new challenges while flying, potentially reducing their risk perception. Reduced risk perception can result in more unsafe behaviors. This relationship is supported by a study conducted by Barrick et al. (2013) reported that individuals with high levels of Openness to Experience desire to have a greater control over what they do and how they do it, and given this nature, individuals high in Openness were more likely to disregard safety rules as a means of establishing higher autonomy.

Individuals who have high scores in Conscientiousness strive to achieve high standards and are self-disciplined, orderly, deliberate, responsible, thorough, and dutiful. In the context of the current theoretical model, CFIs who score high in Conscientiousness may be responsible and compliant to all the safety goals and policies put forth by the flight school. Therefore, the CFIs may execute positive safety behaviors by participating in all the safety goals and being compliant with all the safety procedures within the flight school. This theorized relationship has been supported by studies that have found that Conscientious individuals who are responsible, dutiful, and have a drive towards accomplishment of work-related goals are more likely to have fewer unsafe behaviors in manufacturing (Wallace & Vodanovich, 2003) and professional driving (Siebokaite & Endriulaitiene, 2012) settings.

Individuals who score high in Extraversion are typically warm, talkative, assertive, active, energetic, cheerful, and high in positive affect; they generally like to be around others and prefer stimulating environments. In the context of the current theoretical model, CFIs with high levels of Extraversion may have the tendency to be optimistic and excitement-seeking. This nature of theirs may propel them towards risk-taking behaviors such as taking shortcuts and not using safety equipment, leading to unsafe behaviors. This relationship is supported by a study conducted by Gao et al. (2020) that found that construction workers high in extroversion are more energetic and are more likely to take risks, and this nature could propel them to be involved in unsafe behaviors.

Individuals who score high in Agreeableness are typically altruistic, cooperative, compassionate, appreciative, forgiving, generous, kind, and sympathetic, and they trust others' good intentions. In the context of the theoretical model, CFIs who score high in Agreeableness may be cooperative, generous, and kind towards the student pilots. This nature of the CFIs may help them stay calm during a risky situation while flying with the student pilots and following proper safety procedures. This hypothesized relationship is supported by Barrick et al. (2013), who reported that highly agreeable individuals are driven to behave in a way that fosters and preserves positive and meaningful relationships with others. As a result, individuals high in Agreeableness may be less likely to engage in unsafe behavior as doing so could damage interpersonal relationships with students or coworkers at the flight school.

Individuals who score high in Neuroticism are emotionally sensitive; they often become upset quickly and frequently experience negative emotions and include traits such as sadness, anger, anxiety, worry, self-consciousness, vulnerability to stress, and a tendency to act impulsively. In the context of the current theoretical model, CFIs who score high in Neuroticism may easily be upset with a small mistake by the student pilots while flying. This can lead to impulsive action, which can involve risky behavior, thus leading to unsafe behaviors. Siebokaite and Endriulaitiene (2012) found that individuals high in Neuroticism have the tendency to act impulsively while driving, and this nature led them to engage in more frequent unsafe driving behaviors relative to less neurotic individuals.

Self-Efficacy theory

Augmenting the Big Five personality model and its relationship to safety behaviors is Bandura's (1977) self-efficacy theory. According to Bandura (1981), self-efficacy refers to "judgments of how well one can execute courses of action required to deal with perspective situations" (p. 122). In other words, self-efficacy is how people believe or perceive their ability to carry out a desired action or achieve a goal. Self-efficacy is not related to a person's actual level of competency but instead is concerned with how a person perceives or judges his or her capabilities to perform certain actions (Bandura, 1982). Self-efficacy beliefs may have a larger impact on an individual's actions, emotions, and motivations than their actual skill level (Bandura, 1994). Individuals with high self-efficacy are more likely to engage in certain behaviors when they believe that they are capable of performing the behaviors successfully. In contrast, individuals with low self-efficacy are more likely not to engage in an activity if they believe they will not be successful (Bandura, 1982).

In the context of the current theoretical model, CFIs who are compliant with all the safety-related tasks put forth by the flight school are more likely to have high self-efficacy. These CFIs with high self-efficacy are more likely to have a high confidence in being compliant to all the safety protocols and objectives put forth by the flight school in the future. This nature could lead to more safety behaviors. With these theoretical groundings and the empirical support highlighted above, there is clear support for the development of such a theoretical model. The following sections detail the literature review and analysis methodology utilized to develop the proposed theoretical model and present the resulting model and associated implications.

Methods

A literature review was conducted to identify the existing relationships between the target constructs used in the study and the safety behaviors among workers across various aviation and non-aviation work settings. These relationships included: (a) Personality traits influencing safety behaviors, (b) Risk perception influencing safety behaviors and mediating the relationship between personality traits and safety behaviors, (e) Self-efficacy influencing safety behaviors and mediating the relationship between personality and safety behaviors, (f) Organizational safety climate influencing safety behaviors and moderating the relationship between personality and safety behaviors. Based on these relationships, a literature review was conducted to identify the relevant articles.

Literature was searched using the following databases: ProQuest, Google Scholar, and 4-year private universities' library databases. The following keywords were used: pilots, flight instructors, safety behaviors, personality traits, five-factor model (FFM), Big Five Personality traits, self-efficacy, risk-perception, and mediating and moderating relationships. Although this literature review focused primarily on the Big Five personality factors, the literature reviewed revealed research involving other personality traits, such as proactive personality and authentic leadership personality, which were included given their relevancy to the impact they had on risk-perception, self-efficacy, and safety behaviors. Over 100 abstracts were reviewed for relevancy, and 43 articles published between 1990 and 2020 were selected for full review. Of the 43 articles selected, only 30 articles were thoroughly reviewed and used to extract information pertaining to: (a) the direct effect of personality traits on safety behaviors, (b) the direct effects of self-efficacy and risk-perception on safety behaviors, (c) the mediating effects of self-efficacy and risk perception on the relationship between personality and safety behaviors, and (d) the moderating effects of safety climate on the relationship between personality and safety behaviors. These articles were from seven different domains: aviation, education, nuclear power plants (NPP), construction, driving, athletics, manufacturing, and the general population. The following information was extracted from the reviewed articles: purpose of the study, target population and sample, constructs measured, type of instruments used to collect data, and summary of findings. From each relevant article, any relationships identified between personality traits, self-efficacy, risk perception, safety climate, and safety behaviors were extracted. Based on the relationships identified from the paper review, a matrix was created with a mapping of positive, negative, or lack of relationships between the target constructs of personality traits, self-efficacy, risk perception, safety climate, and safety behaviors. The total frequency counts of studies that supported each relationship were calculated, and based on these frequency counts, a proposed theoretical model was built that determined the direct and indirect relationship between personality traits, self-efficacy, risk perception, safety climate, and safety behaviors among CFIs.

Results

The literature review resulted in 30 articles that met the study's criteria and were analyzed to extract construct relationships. Table 1 summarizes the domains and sample sizes from the studies that were analyzed. A summary of the literature review is presented below and organized based on the relationships being examined, including: (a) Personality influence on safety behaviors, (b) Risk perception influence on safety behaviors and mediating the relationship between personality and safety behaviors, (c) Self-efficacy influence on safety behaviors and mediating the relationship between personality and safety behaviors, (d) Safety climate influence on safety behaviors, and (e) Safety climate moderating the relationship between personality and safety behaviors.

Table 1
Summary of Sample Size Based on Domain

Domain [a]	**Sample Size**	
	N [b]	**%** [c]
Aviation	1980	18.14%
Athletics	211	1.93%
Construction	1130	10.35%
NPP	462	4.23%
Students	302	2.77%
Education	1810	16.58%
Manufacturing	964	8.83%
Driving	324+329	2.97%
General Population	4036	36.97%
Total	10,917,	100%

Note: [a] indicates the domain from which the article was reviewed. [b] indicates the total number of sample sizes from all the articles that were reviewed from each domain. [c] indicates the proportion of the sample from each domain.

Personality Influence on Safety Behaviors

Historically, the significant effects of personality on safety outcomes have been reported across various workplace settings (Barrick et al., 2013; Barrick & Mount, 1991; Christian et al., 2009; Clarke & Robertson, 2008; Gao et al., 2020; Hogan & Foster, 2013). Some studies have also reported personality as a predominant factor in pilots' performance and training (Bartram, 1995; King, 2014; Mesarosova et al., 2018). In a study conducted by Jong-Hyun et al. (2018), significant effects of personality on safety behaviors were found when the effects of personality variables on employees' safety behavior were investigated at a South Korean nuclear and chemical power plant. A survey questionnaire consisting of items related to personality traits and safety behaviors was distributed to a total of 300 workers in nuclear and chemical plants. A total of 243 questionnaires were collected, with a response rate of 81%. Out of the 242 respondents, 215 (88.8%) were men, and 27 (11.2%) were female. John-Hyun et al. reported that Openness to experience ($\beta = .133, p < .05$), Emotionality ($\beta = .142, p < .05$), which is an aspect of Neuroticism, and Honesty-Humility ($\beta = .127, p < .05$), which is an aspect of Conscientiousness, were found to be significantly and positively correlated with safety behaviors.

In another study conducted by Tao et al. (2020), Neuroticism was significantly related to human errors, while Conscientiousness was significantly related to safety participation among nuclear power plant (NPP) commission workers in China. This study's primary goal was to examine the roles of a set of demographics, personality, and attitudinal factors on self-reported safety behaviors (including safety participation and human errors). A total sample of $N = 157$ workers from the NPP participated in the survey. All the data was analyzed using Pearson's bivariate correlations to determine intercorrelations among personality traits and safety behaviors. The results demonstrated that Neuroticism ($r = .37, p < .01$) was significantly and positively related to human errors. A plausible explanation for this is that neurotic people are often impatient, anxious, and irritated (Barrick & Mount, 1991; Clarke & Robertson, 2005). Thus, they might be preoccupied with worry and anxiety, distracted from their tasks, and more likely to commit errors and be involved in accidents. Tao et al.. also reported that Conscientiousness was positively correlated with safety participation ($r = .48, p < .01$). A plausible explanation for this is that conscientious workers possess a high degree of self-discipline and are more willing to take on their responsibilities, such as compliantly adhering to rules for workplace safety.

Qu et al. (2022) conducted a study to investigate the effects of personality traits on the driving behaviors of professional truck drivers. The study used a sample of N = 389 male truck drivers in China. The truck drivers completed a short survey that included a Big Five inventory questionnaire and a driving behavior questionnaire. The driving behavior questionnaire included five subscales: positive driving behavior, aggressive violation, ordinary violation, errors, and lapses. For example, a driver scoring high in the positive driving scale and low in the aggressive violation, ordinary violation, errors, and lapses scale is considered to have safe driving behaviors. Pearson's correlation analysis was conducted to analyze the relationship between the Big Five personality traits and the driving behaviors of the truck drivers. The results indicated that Agreeableness ($r = 0.47, p <.001$), Conscientiousness ($r = 0.38, p <.001$), Openness ($r = 0.27, p <.001$), and Extraversion ($r = 0.17, p <.001$) were positively related to positive driving behavior scale. However, Neuroticism ($r = -0.38, p <.001$) was negatively related to the positive driving behavior scale. The results also indicated that Agreeableness ($r = -0.52, p <.001$), Conscientiousness ($r = -0.55, p <.001$), Openness ($r = -0.45, p <.001$), and Extraversion ($r = -0.38, p <.001$) were negatively related to aggressive violations of the driving behavior scale. Whereas Neuroticism ($r = 0.45, p <.001$) was positively related to aggressive violations of the driving behavior scale. The findings of this study indicated that there was a consistent relationship between the personality traits of truck drivers and their driving behaviors. Truck drivers high in Agreeableness, Conscientiousness, Openness, and Extraversion had lower errors, lapses, and violations, indicating positive safety behaviors. Whereas truck drivers high in Neuroticism had higher errors, lapses, and violations, indicating more unsafe behaviors.

Risk Perception Directly Influencing Safety Behaviors and Mediating the Relationship Between Personality Traits and Safety Behaviors.

Various research in the fields of occupational health safety, workplace safety, and health psychology have found risk perception to have a significant effect on safety-related behaviors (Brewer et al., 2007; Christian et al., 2009; Kraut et al., 2011; Taylor & Snyder, 2017). The relationship between risk perception and pilots' safety behavior has been found to be clearly strong (Ji et al., 2018; Taylor & Snyder, 2017). Taylor and Snyder (2017) conducted a laboratory study to investigate the impact of risk perception on safety behaviors. A total of 80 students were randomly divided into two groups and were asked to perform two seemingly dangerous tasks. The supervisor's commitment to safety was manipulated, and safety behavior was assessed using video data rated by an observer. The results suggested that risk perception, when framed regarding the risk of not performing the safety procedures, was positive ($r = .35$, $p < .01$) related to safety behavior, and as well as to supervisor commitment to safety ($r = .24$, $p < .05$).

Ji et al. (2018) conducted a study to investigate the mediating effect of risk perception on the relationship between proactive personality, which is related to Conscientiousness, and situational judgement among the flying cadets. Situational judgment was defined as the ability to make a low-risk decision during a state of emergency and is therefore related to safety behaviors. A total of $N = 257$ pilots from China's Southern Airlines took part in this study. All of the participants responded to a self-administered questionnaire survey that measured risk tolerance, risk perception, and safety operating behaviors. The data was analyzed using Structural Equation Modeling (SEM) analyses, and hierarchical regression analyses were applied to detect the effects of risk perception on safety operation behaviors among airline pilots. The study hypothesized that risk perception significantly mediates the relationship between flying cadets' proactive personality and situational judgement. The obtained results showed that a proactive personality has both a direct effect and an indirect effect mediated by risk perception on flying cadets' situational judgment. The results demonstrated that the relationship between proactive personality on situational judgment was mediated by risk perception, and this was significant at $p < .001$. Moreover, it was also reported that a proactive personality was positively related to risk perception, and risk perception was positively related to situational judgement among flying cadets. A plausible explanation can be that flying cadets with higher levels of proactive personality were more likely to perceive the risk of a specific flight environment and, consequently, were able to judge more effectively.

In another study, Machin and Sankey (2008) investigated the strength of the relationship between personality factors, risk perceptions, and driving behavior among young, mainly inexperienced drivers. A total of $N = 159$ participants completed the online survey with an age range of 17 to 52 years. The sample was randomly drawn from all the departments of the University of Southern Queensland (USQ) student population. All the data was collected through an online survey that included questions about personality, risk perception, and risky driving behaviors. Machin and Sankey reported Extraversion to be positively and significantly related with risk driving behaviors ($\beta = .18$, $t = 2.27$, $p < .05$), and Agreeableness ($\beta = -.23$, $t = -2.92$, $p < .01$) to be negatively and significantly related to risk driving behaviors. The findings also suggest that young drivers with higher levels of Extraversion and lower levels of Agreeableness reported greater speeding or risky driving behaviors. Abdelrahman (2020) conducted a study to investigate how risk perception mediates the relationship between Big Five Factor personality dimensions and social distancing behaviors among the residents of Qatar. The results demonstrated that Conscientiousness ($r = .27$, $p < .001$) and Neuroticism ($r = .18$, $p < .001$) were positively correlated with social distancing. Additionally, risk perception ($r = .25$, $p < .001$) was also positively related to social distancing (Abdelrahman, 2020). A plausible explanation for this finding can be that individuals high in Conscientiousness are more responsible, and individuals high on Neuroticism are more fearful; these natures may influence them in perceiving higher risk and practicing social distancing.

Self-Efficacy Directly Influencing Safety Behaviors and Mediating the Relationship Between Personality Traits and Safety Behaviors.

Bandura's self-efficacy theory has been extensively studied in the fields of education, sports, military science, commerce, and so forth. Historically, various researchers in the past have demonstrated that an individual's self-efficacy is a significant predictor of safety behaviors across various workplace settings (Adjekulm, 2017; Chen & Chen, 2014; Parasuraman et al., 1993; Prinzel, 2002; Graham & Weiner, 1995). Individual self-efficacy has been observed as a predictor in several studies that investigate pilots' work-related behaviors (Parasuraman et al., 1993; Prinzel, 2002). Moreover, self-efficacy was also found to mediate the relationship between personality and safety behaviors across various domains (Li et al., 2017; Zhang et al., 2020).

Chen and Chen (2014) conducted a study to investigate the effects of self-efficacy on commercial airline pilots' safety behaviors. A total of $N = 239$ commercial pilots from five different Taiwanese airlines participated in the study. A total of 420 survey questionnaires that included the general self-efficacy scale and Neal and Griffin's (2006) safety behaviors scale were either deposited in the pilot's individual mailbox or distributed onboard an aircraft with sealable stamped and addressed envelopes. Chen and Chen used SEM techniques to analyze the data. The results demonstrated self-efficacy has significant ($p < .05$) and direct, positive effects on pilots' safety behaviors. The findings suggested that as the pilots' perceived self-efficacy increased, the safety behaviors measured as safety participation and safety compliance also increased. A plausible explanation could be that individuals with high levels of self-efficacy have greater confidence in their own abilities to achieve specific goals. Therefore, pilots with higher perceived self-efficacy are likely to better resist pressure and devote more effort to improve their safety-related behaviors.

Similar results were found in a study conducted by Li et al. (2018). The primary aim of Li et al.. was to explore the relationship between self-efficacy, work engagement, flight experience, and human error and safety behaviors among pilots during in-flight missions. A total of $N = 143$ airline pilots took part in the study. All the pilots participating in the study completed three questionnaires: the Perceived Professional Self-Efficacy Scale (PPSEC), the Utrecht Work Engagement Scale (UWES), and the Safety Operation Behavior Scale (SOBS). The data was analyzed using correlation analysis. The results indicated that self-efficacy, work engagement, and human error and safety behaviors were significantly correlated with each other. Li et al. also reported that through causal steps regression and bootstrap analysis, the airline pilots' self-efficacy significantly influenced their human error and safety behaviors. Self-efficacy accounted for about 22.3% variance in human errors, and this was significant at $p < .001$(Li et al., 2018).

The findings also suggest that pilots with higher self-efficacy are less likely to be involved in human errors and unsafe behaviors. The results of this study were also consistent with the previous investigation that investigated self-efficacy as a predictor of job performance (Alessandri et al., 2015; Tims et al., 2014).

Similar results were found in another study conducted by Adjekulm (2017), who investigated the effects of self-efficacy on safety participation and safety compliance in a collegiate aviation program of a publicly owned university in the United States. The study used a total of $N = 800$ students enrolled in flight-related courses at the university. A total of $N = 282$ responses were completed beyond the consent page and used for analysis. Out of the 282 respondents, 247(87.6%) were male, and 35 (12.4%) were female. All the participants responded to a 46-item questionnaire that included items related to the constructs of self-efficacy, safety participation, and safety compliance. The results of Adjekulm 's study demonstrated that self-efficacy has a strong direct effect on safety compliance. This finding was also in support of Chen and Chen's (2014) result that indicated self-efficacy as a significant predictor of safety-related behaviors. A plausible explanation for this finding is that student pilots with higher self-efficacy may project high levels of motivation, and this confidence of theirs may help them in being compliant to all the required safety behaviors put forth by the flight school.

A study was conducted by Zhang et al. (2020) to identify the factors that contribute to mobile phone use while driving (MPUWD) for food delivery. The study used a total sample of $N = 315$ food deliverymen, and the sample was collected through the snowball sampling strategy. All the participants in the study completed a self-reported questionnaire that included items related to demographics, personality traits, risk perception, driving self-efficacy, and mobile phone use while driving. Results from SEM analysis and bootstrapping techniques indicated that self-efficacy partially mediated the relationship between personality traits of (a) Psychoticism, which embodies traits such as impulsivity and lack of sympathy, and (b) Extraversion and MPUWD behaviors. The findings indicated self-efficacy mediated the effect of personality traits such as Psychoticism (r = .18, p < .01) and Extraversion ($r = .12$, $p < .05$) on MPUWD behaviors. However, self-efficacy fully mediated the relationship between these personality traits and risk perception ($r = .54$, $p < .001$). The SEM estimates and bootstrap estimates suggest that although the personality traits of the deliverymen had a direct influence on their MPUWD behaviors, self-efficacy was found to be an antecedent factor before the MPUWD behavior. A plausible explanation is that the food delivery driver's motivation to deliver the food in a timely manner may engage them in using the mobile more frequently while driving.

In a study conducted by Li et al. (2017), it was found that the impact of proactive personality, related to Conscientiousness, on teachers' innovative work behavior was mediated by creative self-efficacy. A total of $N = 352$ valid questionnaires were returned, with a response rate of over 95%. All the participants responded to a self-administered questionnaire related to proactive personality, innovative work behaviors, and creative self-efficacy. The results demonstrated that proactive personality ($r = .31$, $p < .01$) positively correlated with creative self-efficacy, and self-efficacy ($r = .28$, $p < .001$) was significantly correlated with teachers' innovative work behaviors (Li et al., 2017). Based on the above results, Li et al. also suggested that creative self-efficacy fully mediates the relationship between proactive personality and innovative work behaviors among teachers. A plausible explanation for this may be that the proactive nature of the teacher may give them the advantages of being dutiful and responsible, increasing cognitive flexibility, and this helps them in achieving higher levels of creative self-efficacy, thus helping them implement innovative processes.

Safety Climate Influence on Safety Behaviors

Various studies in the past have confirmed the relationship between safety climate and safety behaviors (He et al., 2020; Kouabenan et al., 2015; Lu & Tsai, 2010). Lu and Tsai (2010) conducted a study to investigate the effects of a safety climate on the safety behaviors among seafarers working on a container ship. The safety climate was measured by understanding the seafarers' perception of their company's safety policy and safety management. The study investigated two hypotheses: (a) Safety policy will be positively related to seafarers' safety behavior in container shipping, and (b) Safety management will be positively related to seafarers' safety behavior in container shipping. A total of 773 seafarers from 13 countries working in 124 different vessels participated in the study. All the participants in the study responded to a 26-item questionnaire that included items related to safety, climate, and safety behaviors. As there were participants from China (133) and Taiwan (208), a Chinese version of the questionnaire was also prepared. The data was analyzed using a Chi-square test. The results indicated that overall model fit was significant χ^2 (183) = 687.84, $p < .00$, safety policy had a significant and positive effect on seafarers' safety behaviors ($\beta = 0.29$, $p < .05$). However, safety management was positively related to safety behavior but not significant ($\beta = 0.78$, $p > .05$). The findings of the study indicate that higher management safety policies, goals, and priorities influence the safety behaviors of seafarers. The findings also indicate that when seafarers perceive that a strong emphasis is given by their organization on safety policy and safety management, they are more likely to have positive safety behaviors.

In a study conducted by Kouabenan et al. (2015), it was found that there was a positive relationship between safety climate and involvement in safety management among the First Line Managers (FLMs) working at nuclear plants in France. Safety management was defined as "the extent to which FLMs undertake the preventive actions from involving in a high-risk situation" (Kouabenan et al., p. 5, 2015). In the context of the proposed study, safety management is related to safety behaviors. For example, an FLM who has a high involvement in safety management is less likely to be involved in unsafe behaviors and, therefore, displays positive safety behaviors. The study used a sample of 63 FLMs from two different nuclear plants. The sample included FLM's maintenance (54.1%), production (21.3%), logistics (8.2%), risk prevention (8.2%), and services (8.2%). All the data was collected in a questionnaire that included items related to safety climate, perceived risk, and safety management. The data were analyzed using SPSS 20.0 software. The results indicated that there was a positive and significant relationship between safety climate and involvement in safety management ($r = .757$, $p < .01$). The findings suggested that FLMs who perceived to have a high safety climate were more likely to have a high involvement in safety management.

In another study conducted by He et al. (2020), it was found that there was a positive association between safety climate and safety behaviors among workers and supervisors working at construction organizations in China. The study investigated two hypotheses related to the association of safety climate and safety behaviors: (a) Safety climate is positively related to safety compliance of construction workers and supervisors, and (b) Safety climate is positively related to safety participation of construction workers and supervisors. The results indicated that the safety climate was both significant and positively related to safety compliance ($r = .52$, $p < .01$) and safety participation ($r = .58$, $p < .01$) among construction workers and supervisors. The findings of the study also align with previous studies (Kouabenan et al., 2015; Lu & Tsai, 2010) that indicated that employees who perceive a high safety climate are more likely to have positive safety behaviors.

Safety Climate as a Moderating Variable

In this section, a presentation of the studies that investigated the moderating effects of safety climate on the relationship between personality and safety behaviors is given. Rajabi et al. (2020) conducted a cross-sectional study to examine the moderating effects of safety climate on the relationship between personality traits and safety performance. A total sample of $N = 487$ operational staff working at a gas refinery in Iran participated in the study. One of the hypotheses of Rajabi et al. 's study was that a safety climate has a moderating effect on the relationship between Impulsiveness, which is a personality trait that is closely related to Neuroticism (Garcia-Argibay, 2019), and safety performance. The results of the study indicated that Impulsiveness had indirect negative correlations with safety compliance ($r = -.28$, $p < .01$) and safety participation ($r = -.22$, $p < .01$; $\beta = -0.075$; Rajabi et al., 2020). Results also showed that safety climate had a direct positive correlation with safety compliance ($r = -.35$, $p < .01$) and safety participation ($r = -.36$, $p < .01$). The results of the study also indicated that a significant relationship between Impulsiveness, safety compliance, and safety participation was being moderated by safety climate ($R^2 = 0.20$, $p < .001$). The findings suggested that a higher safety climate weakens the direct effects of Impulsiveness traits on safety compliance and safety participation among operational workers at gas refineries in Iran. As the Impulsiveness personality trait is closely related to Neuroticism (Garcia-Argibay, 2019), when applied to the context of the FFM, a higher safety climate is proposed to weaken the negative and direct effects of Neuroticism on safety behaviors.

Doerr (2020) conducted a study to examine when and how safety climate moderated the relationship between personality traits and workplace safety behaviors. A total of N = 492 participants took part in the study. All the participants were full-time employees working in various organizations in the United States. All the participants responded to a Qualtrics survey that included items related to their current job roles, personalities, perceptions of safety climate, and self-reported ratings of their own safety behaviors. Results indicated that safety climate moderates the relationship between personality traits of Conscientiousness and Extraversion and safety behaviors. It was also found that the moderation effect of the safety climate on the relationship between Conscientiousness and safety behaviors was significant at $p < .001$ (Doerr, 2020). This finding suggests that when employees' perception of safety climate was high, the relationship between Extraversion and safety behaviors was moderated by safety climate. These finding suggests that "personality traits are related to safety behaviors and an organization's safety climate could encourage or discourage the employees from being compliant to the safety procedures in the organization" (Doerr, 2020, p. 280).

Lee and Dalal (2016) conducted a study to investigate whether safety climate moderates the relationship between Conscientiousness and safety compliance among employees working at manufacturing organizations in South Korea. The study used a sample of 964 participants. Conscientiousness was measured by an 8-item Conscientiousness subscale from Saucier (1994). The safety climate was measured by using the Safety Climate scale developed by Griffin and Neal (2000). Safety compliance was measured with Neal and Griffin's (2006) scale. The study used a hierarchical linear modeling strategy to analyze the data. The results of the study indicated that the interaction between Conscientiousness and safety climate was statistically significant for safety compliance ($r = -.65$, $p < .01$). Specifically, the findings indicated that higher safety climate weakens the positive and direct effects of Conscientiousness on safety behaviors The findings of the study also suggested that the relationship between Conscientiousness and safety compliance was stronger in weaker safety climates than in strong ones.

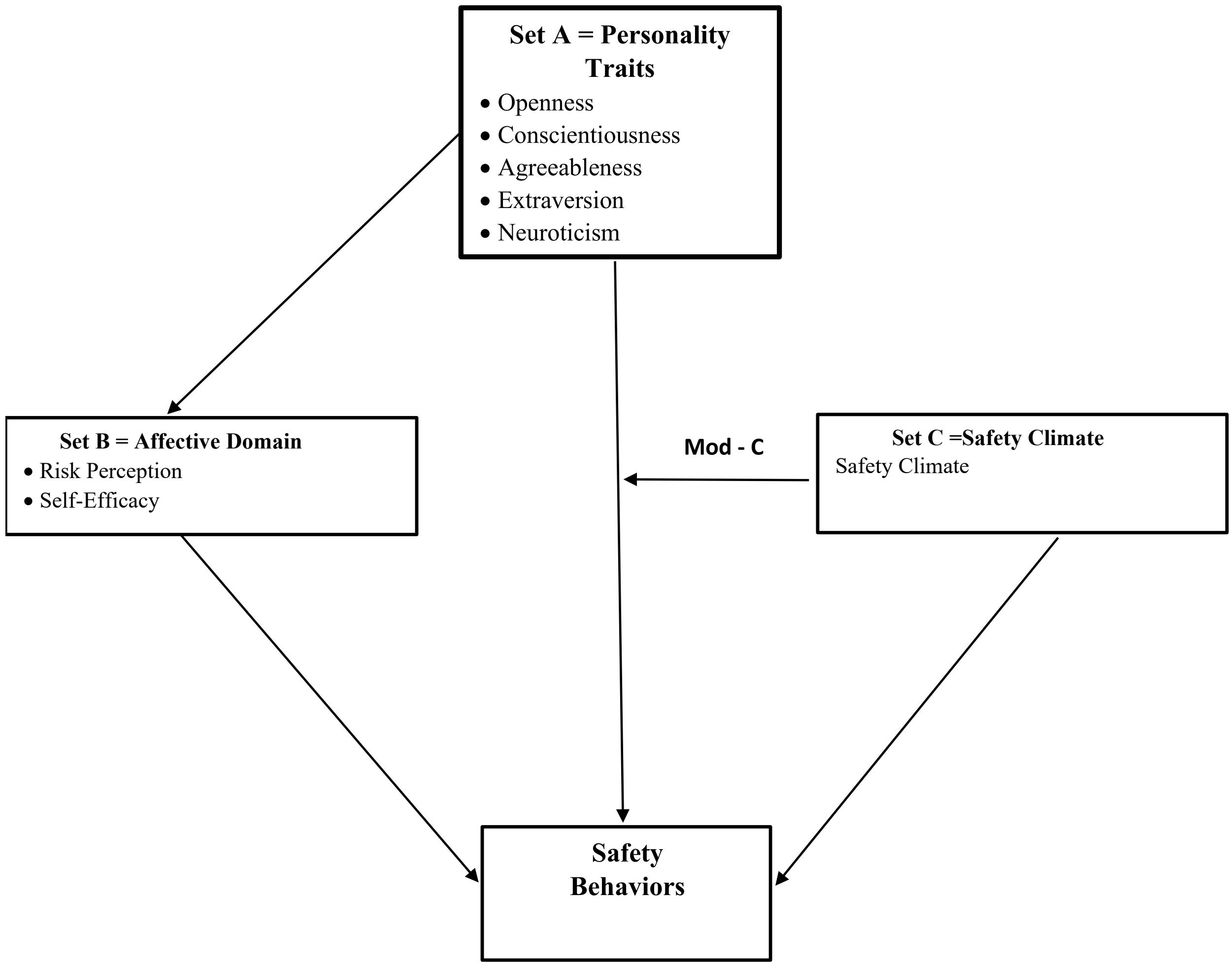
In a study conducted by Ji et al. (2019), it was found that safety climate moderated the relationship between personality and safety behaviors. A total of $N = 547$ flight attendants working for China Southern Airlines Limited took part in the study. A hierarchical regression analysis was conducted to test the moderating effect of safety climate on the relationship between proactive personality, which has been shown to be related to Extraversion, Agreeableness, and Conscientiousness (Bateman & Crant, 1993; Funder, 2001) and safety behaviors in flight attendants. The results demonstrated proactive personality and safety climate to be significantly correlated with safety behaviors ($r = .32$, $p < .01$; $r = .78$, $p < .01$). Furthermore, a significant positive interaction between proactive personality and safety climate was also found ($r = .25$, $p < .01$). Specifically, the findings indicated that higher safety climate weakens the positive and direct effects of proactive personality on safety behaviors and this interaction was significant at $p < .05$ (Ji et al., 2019). Whereas in organizations with a lower safety climate, the relationship between proactive personality and safety behaviors is stronger. A plausible explanation for this finding is that flight attendants working in an organization with a high safety climate are more likely to display positive safety behaviors regardless of their proactive personality traits. Whereas flight attendants working in an organization with a low safety climate, their proactive personality traits are more likely to influence their safety behaviors.

Similar to Ji et al. (2019), Baba et al. (2019) investigated the moderating effects of service climate on the relationship between proactive personality and service performance. The study used a self-administered questionnaire to collect data from a sample of $N = 485$ flight attendants, pilots, engineers, and service employees working at Chinese airlines. The questionnaire included items from the proactive personality scale, safety climate scale, and job performance scale. The data was analyzed using hierarchical regression analysis. The findings also suggested that the positive relationship between proactive personality and performance was observed only when the safety climate was perceived as high but not when it was perceived as low. Unlike the previous studies (Ji et al., 2019; Lee & Dalal, 2016), these findings were opposite in direction and suggested that the positive influence of proactive personality on performance is nullified where the safety climate is perceived to be low. A plausible explanation could be that individuals high in proactive personality are more likely to have positive safety behaviors; however, working in an organization with a low safety climate may lower their commitment towards safety, leading to unsafe behaviors.

Proposed Theoretical Model

Based on the findings from the reviewed literature, the following theoretical model is proposed in Figure 1. For the context of the current study, the research variables have been divided into three functional sets. Set A = Personality traits consist of five facets of personality traits, including Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Set B, = Affective domain, was defined as “a learner’s emotions toward the learning experience. It includes feelings, values, enthusiasm, motivation, and attitudes” (FAA, 2008, pp. 2–14). In the context of the current study, an affective domain consists of self-efficacy and risk perception. Set C = Safety Climate consists of safety climate.

Figure 1
Proposed Theoretical Model



Note. Mod – C indicates the moderating effect of the safety climate on the relationship between personality traits and safety behaviors.

The theoretical model proposes that: (a) CFIs' personality traits as measured by CFIs levels of Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness will directly influence their safety behaviors; (b) CFIs' self-efficacy and risk-perception named as affective domain variables will have a direct influence on their safety behaviors; (c) CFIs' safety climate will directly influence their safety behaviors; (d) CFIs' self-efficacy and risk-perception will mediate the relationship between CFIs' personality traits and safety behaviors; and (e) Flight school's safety climate, as measured by CFIs' perceived management commitment to safety, safety training, and equipment and maintenance, will moderate the relationship between CFIs' personality traits and their safety behaviors.

Discussion

The studies reviewed in this paper demonstrated the extent to which personality traits, self-efficacy, risk-perception, and safety climate impact safety behaviors across various domains.

The results of these studies, in conjunction with Big Five personality model (1990) theory and Bandura's self-efficacy (1977) theory, provide support for the proposed theoretical model. When examining the effect of Big Five Personality traits on the safety behaviors of CFIs, the model proposes that Extraversion, Conscientiousness, Openness, and Agreeableness are more likely to have a positive relationship with CFIs' safety behaviors. However, Neuroticism will tend to have a negative relationship with CFIs' safety behaviors. When examining the relationship between risk perception, self-efficacy, and safety behaviors of CFIs, our model proposes that both risk perception and self-efficacy will have a positive relationship with CFIs' safety behaviors. In addition to the direct relationship, our model also proposes the indirect effects of self-efficacy and risk perception on the relationship between CFIs' personality traits and safety behaviors.

The model proposes that CFIs' self-efficacy will mediate the relationship between CFIs' personality traits of Neuroticism, Extraversion, Conscientiousness, and safety behaviors, and CFIs' risk perception will mediate the relationship between CFIs' personality traits of Conscientiousness, Neuroticism, and safety behaviors. When examining the relationship between safety climate and safety behaviors, the model proposes that flight schools' safety climate will tend to have a positive relationship with CFIs' safety behaviors. Moreover, our model also proposes that CFIs' flight school's safety climate will moderate the relationship between CFIs' personality traits and safety behaviors.

The practical implications of the proposed theoretical model are that it may provide insight to flight training organizations and CFIs in developing a clear understanding of how CFIs' personality could influence propensity towards risk-taking behaviors. These findings also provide flight schools insight with respect to the linkage between CFIs' personality types, risk perception, self-efficacy, and their safety behaviors. This could help the flight schools in building new safety procedures or protocols to accommodate CFIs of all personality types and enhance safety performance. Flight schools need to understand the impact a safety climate has as it can mitigate some of the negative effects of personality. The findings may also help the flight schools in understanding the impact of personality on safety behaviors as there is a potential to consider this in their hiring practices as well as training. Perhaps training can be adapted based on personality traits. The findings of the proposed study may also help flight schools in understanding the role of the safety climate in CFIs' safety behaviors. This could help the flight schools in building new safety goals, in which every CFI is motivated to contribute, to the best of their abilities, towards safety goals.

A caution to the reader is provided here that the results must be interpreted given the potential for limitations in generalizability due to the studies being from different domains and cultures, which may result in different relationships. The recommendation for future research will be to test the theoretical model by collecting empirical data from CFIs across the United States. By conducting an empirical study in the future, the theoretical model can be validated. If obtained results in the future align with the proposed model, it will provide support for the indirect effects of affective domain variables such as risk perception and self-efficacy on the relationship between the personality traits and safety behaviors along with the direct relationships among the constructs. Moreover, the empirical findings in future research can also inform the aviation community about the role of the safety climate in the relationship between the personality traits and safety behaviors of the CFIs.

Conclusions

There has been a great deal of research conducted in the past to investigate the effects of personality traits on safety behaviors across various work settings. However, there is a dearth of research that examined the relationship between the personality traits of CFIs and their safety behaviors. Similarly, most of the studies in the past have investigated the individual effects of affective domain variables and safety climate on safety behaviors. Limited research was conducted that examined the mediating and moderating effects of affective domain variables and safety climate on the relationship between personality traits and safety behaviors. A literature review was thoroughly conducted to examining the information related to: (a) the direct effect of personality traits on safety behaviors, (b) the direct effects of self-efficacy and risk-perception on safety behaviors, (c) the mediating and moderating effects of self-efficacy and risk perception on the relationship between personality and safety behaviors, and (d) the moderating effects of safety climate on the relationship between personality and safety behaviors. These articles were from seven different domains: aviation, education, nuclear power plants (NPP), construction, driving, athletics, manufacturing, and the general population. The results indicated the proposed theoretical model: (a) CFIs' personality traits as measured by CFIs levels of Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness will directly influence their safety behaviors; (b) CFIs' self-efficacy and risk-perception named as affective domain variables will have a direct influence on their safety behaviors; (c) CFIs' safety climate will directly influence their safety behaviors; (d) CFIs' self-efficacy and risk-perception will mediate the relationship between CFIs' personality traits and safety behaviors; and (e) Flight schools' safety climatewill moderate the relationship between CFIs' personality traits and their safety behaviors.

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The Status of Safety Management Systems and Fatigue Risk Management Systems at Collegiate Flight Training Institutions

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The purpose of this study was to determine the status of Safety Management Systems (SMS) and Fatigue Risk Management Systems (FRMS) development and implementation at Collegiate Flight Training Organizations across the United States. The research questions focused on demographics, organizational support, and the components of SMS and FRMS at collegiate flight schools. The research followed the model of a previous study published in 2017 by Robertson et al. (2017). Overall, most SMS components increased in implementation or remained unchanged since 2017. The FRMS implementation was relatively low when compared to SMS implementation.

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Introduction

Safety Management Systems (SMS) continue to gain traction in various aviation industry areas and are now regulatory for Part 139 airports. While airlines have been using SMS for nearly 20 years and under regulation for nine years, flight training institutions still lack regulatory requirements for SMS implementation. Robertson et al. (2017) investigated the status of SMS development and implementation in collegiate flight institutions. Given the increased popularity and regulatory demands of SMS in the industry, this is an excellent time to revisit the Robertson et al. (2017) study, adding an investigation into the implementation of Fatigue Risk Management Systems (FRMS).

Fatigue poses a serious issue in aviation safety management, as it can lead to decreased performance and a higher risk of errors among pilots and other personnel (ICAO, 2011). It diminishes situational awareness and accuracy in decision-making, both of which are essential for safe aviation operations (Bongo & Seva, 2021). Previous studies indicate that collegiate students struggle to achieve a sufficient quantity and quality of sleep, resulting in fatigue (Keller et al., 2020; Levin et al., 2019). According to Keller et al. (2022), flight training programs must incorporate training and education focused on fatigue to mitigate associated risks. Consequently, many organizations have begun integrating Fatigue Risk Management (FRM) into their SMS to tackle this issue. However, the absence of FAA regulatory requirements for Part 141 programs allows these programs to avoid establishing SMS and FRMS programs. This study aims to delineate the status of UAA-member Part 141 collegiate aviation flight programs in developing and implementing FRMS at their respective institutions.

Research Questions

This study aims to determine the status of SMS and FRMS development and implementation at UAA-member collegiate flight schools across the US. The following four research questions were used to assess the status of the development and implementation of SMS and FRMS at collegiate flight schools, with the first three coming from the original study by Robertson et al. (2017):

1. What are the SMS demographics of collegiate flight schools?
2. What level of organizational support is reported for SMS by collegiate flight schools?
3. What progress is being made toward the development or implementation of the components of SMS at collegiate flight schools?
4. What progress is being made toward the development or implementation of the elements of FRMS at collegiate flight schools?

Literature Review

Sleep & Fatigue

The aviation industry has recognized fatigue as a critical human-factors-related safety issue due to its impact on pilot performance. In fact, the NTSB has identified fatigue as a contributing factor in 23% of aviation accidents between 2001 and 2012 (Romero et al., 2020). The International Air Transport Association (IATA) reported that pilot fatigue contributed to 31 aircraft accidents in commercial aviation between 2005 and 2022 (Sieberichs et al., 2024). Notably, from 2012 through 2022, approximately 73% of all fixed-wing general aviation accidents involve human error as a probable error or contributing factor. Moreover, 14% of these accidents are associated with flight training operations, including Part 141 operations (Keller et al., 2022). The aviation industry is particularly susceptible to the consequences of fatigue because of continuous operations. The International Civil Aviation Organization (ICAO) defines fatigue as:

> a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety related duties. (ICAO, 2011, p. 1-1)

In other words, fatigue can be defined as a state of mental and physical exertion that requires sleep for the body to recover (ICAO, 2011). The National Transportation Safety Board (NTSB) has identified fatigue as a safety hazard because fatigue hinders a person's ability to remain awake, sharp, and vigilant when completing their duties (Keller et al., 2020). A pilot may experience common symptoms of fatigue such as (1) inattention, (2) reduced cognitive ability, (3) decreased memory, (3) impaired judgment, and (4) decreased reaction time (Levin et al., 2019).

Specifically, fatigue degrades a pilot's ability to anticipate events, plan, and make sound decisions, as documented by the NTSB's pilot error statistics. The NTSB reported that pilots who experienced fatigue were 40% more likely to make errors (Keller et al., 2020). Moreover, the data indicates that errors of omission increased by 75%, and errors while monitoring automation increased by 136% among pilots who were experiencing fatigue (Keller et al., 2020). Typically, the errors committed by pilots experiencing fatigue were related to (1) spatial disorientation, (2) manual dexterity, (3) cognitive processing, and (4) critical thinking skills (Levin et al., 2019). Nevertheless, it is evident that pilot fatigue significantly impacts flight safety.

Fatigue mitigation strategies include proper nutrition, exercise, and a consistent sleep routine (Levin et al., 2019). These strategies may be difficult for pilots to implement due to their irregular work schedules and moving to different time zones worldwide. Pilots may also use self-assessment tools, such as a Flight Risk Assessment Tool (FRAT) and the IM SAFE (illness, medication, stress, alcohol, fatigue, and emotions) checklist, to assist in determining if they are fatigued and fit for flight (FAA, 2022). Also, Part 121 certificate holders can develop effective fatigue mitigation strategies for their pilots by developing their Fatigue Risk Management System (FRMS).

Fatigue Risk Management System (FRMS)

ICAO defines a FRMS as:

> A data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness. (ICAO, 2011, p.1-1)

FRMS builds upon Safety Management Systems (SMS) principles that allow organizations to maintain parity between safety, productivity, and costs. The cornerstone of SMS and FRMS is promoting an effectual safety reporting culture (ICAO, 2011). The Federal Aviation Administration (FAA) requires each Part 121 certificate holder to have an approved Flight Risk Management Plan (FRMP). The FRMS is an alternative method of compliance (AMOC) to the limitations provided by the FAA concerning duty time for crewmembers ("Flight and Duty Limitations," 2012; FAA, 2013). The FRMS, when used as an AMOC, must clearly demonstrate that it meets or exceeds the fatigue management guidelines provided by the FAA (FAA, 2013).

FRMS adopts a varied approach to managing fatigue risk. The minimum required components of an FRMS are (1) policy and documentation, (2) fatigue risk management processes, (3) safety assurance processes, and (4) promotion processes (ICAO, 2011). The FRMS is an iterative process that begins with data collection and ends with an assessment that results in improvements to the system. The first two steps in the FRMS process involve collecting data and identifying fatigue risks. The final two steps in the process incorporate developing and implementing effective fatigue mitigation strategies, with the concluding step assessing these strategies for efficacy (ICAO, 2011). It is imperative that the data is shared between the SMS and FRMS because the goal of both systems is to identify and mitigate safety risks within an organization. The safety data generated within the FRMS is also a component of the SMS.

Safety performance indicators (SPIs) are specific measures that need to be continually monitored and may pinpoint fatigue hazards (Gander et al., 2014). SPIs are also used during the assessment process to determine if the FRMS meets its objectives. Generally, SPIs are organized into two categories based on the data collection type. Operational SPIs are based on data related to the operations of the Part 121 certificate holder, such as the crewmembers' schedules (Gander et al., 2014). Crewmember SPIs involve data personally related to the crewmember, such as sleep loss or diminished quality of sleep (Gander et al., 2014). SPIs are integral to the first two phases of the FRMS process. SPIs guide which data should be collected and how the data should be analyzed. Although the FRMS possesses an internal monitoring process to determine the program's efficacy, the aviation community has conducted research regarding fatigue and its impact on safety, as well as the use of FRMS as a mitigation strategy.

FRMS – Commercial Operators

The common goal of fatigue management is to reduce sleep loss and increase sleep quality (Gander et al., 2019). More research is needed to determine the amount of sleep recovery necessary for pilots after experiencing persistent sleep restriction (Gander et al., 2019). That is, the aviation industry has not yet determined the duration of each recovery sleep event, along with the number of consecutive recovery sleep events necessary to recover from persistent sleep restriction. The aviation industry often operates around the clock, significantly contributing to sleep restriction and fatigue. In addition, extended workloads, early departures, late arrivals, multiple flight legs, and varied time zones impact fatigue for pilots flying for Part 121 carriers (Mendonca et al., 2019). Research has shown that quality sleep in sufficient amounts is the best strategy to avoid fatigue; however, controlled napping before and during flight, proper nutrition, and regular exercise are also effective tools. Caffeine use is an unhealthy response to fatigue, yet it is the primary strategy pilots use to combat fatigue (Mendonca et al., 2019). Much more research is needed to ascertain the most effective means for combating fatigue. To that end, larger and more diverse data sets are needed to determine which factors need to be modified to improve the effectiveness of SPIs (Gander et al., 2014). Although much has been learned about fatigue and effective fatigue mitigation strategies, little progress has been made in this area for collegiate flight training.

Fatigue & Collegiate Flight Training

The causes of fatigue experienced within collegiate flight training differ from those experienced by Part 121 pilots. Nonetheless, there are some similarities, such as poor quality of sleep, long work hours, and irregular sleep schedules (Romero et al., 2020). Collegiate flight training students are younger than Part 121 pilots and may not have developed effective lifestyle habits that inhibit fatigue. For example, nearly 30% of college students report getting insufficient sleep (Romero et al., 2020). In another survey, 66% of the students reported insufficient sleep (Levin et al., 2019). In fact, 95% of collegiate flight students and instructors indicate that fatigue has negatively impacted their flight training (Romero et al., 2020; McDale & Ma, 2008). Another research study found that half the flight training students admitted they had difficulty staying awake during a training flight due to fatigue (Mendonca et al., 2019). Of these responses, 78% of the students stated they had made mistakes during a training flight because of diminished situational awareness and judgment (Mendonca et al., 2019). During additional research, approximately 60% of the student participants indicated in the Collegiate Aviation Fatigue Inventory (CAFI) that they had experienced mental and physical symptoms of fatigue during flight training (Mendonca et al., 2021). Collegiate flight training students must balance their academic workload along with their flight training, while many work part-time jobs as well. Due to this extensive workload, flight training students often do not get sufficient sleep, and their sleep quality is often poor due to living arrangements that are not conducive to proper sleep. Research indicates that half of the students surveyed go to bed between 11:00 pm and midnight when they have school the next day, and more than half stated that their sleep is often interrupted at least once during the night (Romero et al., 2020).

Effective lifestyle habits are essential for reducing fatigue, yet many flight training students have not developed these habits. Half the flight training students do not exercise regularly, and over half stated they have unhealthy eating habits (Levin et al., 2019). Most flight training students and flight instructors indicated in research surveys that adequate sleep and a healthy lifestyle are the primary personal solutions to mitigate fatigue (Levin et al., 2019; McDale & Ma, 2008). Flight instructors responded similarly by attributing fatigue to long workdays and insufficient sleep as the primary contributors to fatigue (McDale & Ma, 2008). Flight instructors favored solutions to fatigue, such as a place to rest at work, increased pay to allow instructors to reduce their workload, and training that helps instructors understand fatigue and how to manage it (McDale & Ma, 2008). The overall theme of the research findings indicates that fatigue negatively impacts the safety of collegiate flight training. Much has been done to develop and implement effective fatigue risk mitigation strategies for Part 121 certificate holders, yet this is not true for collegiate flight training. In fact, 85% of students and flight instructors stated in a research survey that they had received no fatigue-related training (Keller et al., 2020). However, collegiate flight training can use the principles encapsulated in the FRMS model to develop an effective fatigue risk management program that satisfies the needs of collegiate flight training. Specifically, there is a need for improved training and education efforts that include crucial topics such as the causes of fatigue, fatigue awareness, effective sleep strategies, time management, and healthy lifestyle habits (Keller, 2022).

Methodology

This study used a survey instrument approved by the Southern Illinois University Carbondale (SIUC) Institutional Review Board (IRB) to address the four research questions. At the time the survey was distributed, the study population comprised 115 University Aviation Association (UAA) member institutions. The UAA is committed to advancing higher education institutions (HEI) and providing degree-granting aviation programs across various aviation segments. The sample of 95 safety officers came from a list maintained by the UAA Safety Committee. The selected safety officers represented 19 HEIs with active safety programs. The researchers sent two rounds of email communication to the 95 safety officers requesting participation in the survey. Of the 95 safety officers contacted, 21 safety officers from 19 HEIs completed the survey, resulting in a 22% response rate.

Advisory Circular (AC) 120-92B was a guiding framework for developing the survey items (FAA, 2015). While initially developed to assist airlines in meeting regulatory requirements within 14 CFR Part 121 operations, this AC offers a concise and thorough overview of SMS, including its components and the specific elements that underpin SMS, forming the foundational structure of the survey. Robertson et al. (2017) played a critical role in refining the survey instrument, leveraging the knowledge of safety professionals within the flight training domain. Additionally, recognized safety specialists from Embry-Riddle Aeronautical University, Southern Illinois University, and the University of North Dakota evaluated the survey for validation.

Determining SMS and FRMS Implementation

This study created a classification system using AC 120-92B, the current Advisory Circular at that time, as a guide to assess the extent of SMS and FRMS implementation in pilot training programs for managing safety initiatives. The classification system utilized the four components of SMS as a foundational structure and then incorporated the specific elements associated with each SMS component. For example, an HEI with a pilot training program that integrates all four SMS components and their respective elements could possess a fully implemented SMS. This information enables the calculation of an overall degree of SMS and FRMS implementation across the participating HEIs through pilot training programs. For instance, safety risk management (SRM) consists of five separate components. If all five SRM components are present in all 19 participating institutions, as reported by the 21 participating safety officers, the SRM implementation score is determined to be 100%. Similar scoring applies to FRMS implementation.

Acknowledging the limitations in calculating implementation scores, which consist of two factors limiting the use of these scores, is critical. The first limiting factor is that the SMS elements specified in Appendix A originate from AC 120-92B, which serves as a guide rather than a regulatory framework. The purpose of creating AC 120-92B is to assist 14 CFR Part 121 operators in executing and administering an SMS, not to dictate methods used. Further, the elements of FRMS specified in Table 1 originate from AC 120-103A, which, like AC 120-92B, acts as a guiding document and not a regulation regarding the implementation of FRMS. It is also important to note that the method used to assess SMS and FRMS implementation lacks validation. Nevertheless, additional research may demonstrate its relevance as a tool for gauging overall SMS and FRMS implementation in pilot training schools or any other sector within the aviation industry.

The second limitation stems from the variability in SMS and FRMS elements among different institutions. For instance, the survey prompts respondents to enumerate all elements utilized in safety promotion. One of the listed items is using safety stand-downs as a promotional factor. While it is acknowledged that safety stand-downs can be a valuable promotional tool, they are not mandatory for achieving a fully implemented SMS. Therefore, there is a limitation in achieving a perfect implementation score of 100%. Regardless, the scoring system retains its significance as a general guide for evaluating the overall implementation status of SMS and its components. The four components of SMS and FRMS, and the associated elements that safety programs should incorporate for SMS and FRMS implementation, are outlined in Appendix A. Certain elements and processes listed under safety promotion may be optional for SMS implementation.

Other limitations include the potential for bias in self-reported data and the small sample size. The participants self-reported all data collected in this study, meaning there is potential bias in the reported information. Additionally, the initial sample was intentionally small, as this replicates the 2017 study conducted by Robertson et al., which focused on safety officers associated with UAA-member institutions. The 22% response rate further restricts the generalizability of the results.

Results

The survey was divided into four sections that collectively answered the four research questions. The initial part pertains to general SMS demographics, the second involves the level of management commitment to SMS activities, the third relates to the advancement of collegiate flight schools in implementing SMS, and the final part relates to implementing FRMS elements.

The two rounds of email resulted in participation from fewer than half of the population. Of the 95 safety officers emailed, 21 responded to the survey, generating a response rate of 22%.

Part 1 - SMS Demographics

This study aims to gather general SMS demographic data regarding Part 141 collegiate flight programs. Such information is valuable for tracking the adoption of SMS across the collegiate aviation sector. Similar to the research conducted by Robertson et al. (2017) on implementing SMS within airport operations, this study seeks to expand the line of research by observing SMS implementation in collegiate flight schools.

Basic Institutional Demographics

The survey aimed to ascertain the general demographic information about SMS and FRMS at collegiate flight schools. Participants shared essential details about their school in the initial phase, including its name, certification as a Part 141 pilot school, and whether it offers flight instruction directly or through a third-party provider. The identities of the 19 participating institutions were anonymized to maintain their confidentiality. Of the 21 survey respondents, all indicated that their institutions were classified as Part 141 pilot schools. Five (23.8%) of those institutions indicated that they provide flight training to pilots through a third party.

General SMS Demographic Information

The next section of the survey prompted participants to specify their familiarity with SMS to collect demographic information regarding SMS within the participating institutions. Additionally, participants provided details regarding the extent of SMS utilization within their respective pilot training programs. Finally, participants indicated the anticipated timeline for implementing SMS within their organizations.

Table 1 displays the respondents' level of familiarity with SMS. Among the 21 safety officer respondents, all reported being “Knowledgeable” of SMS, and 10 (46.62%) indicated they were “Very Knowledgeable” about SMS or an “SMS expert.” The data shows that all participants have at least a foundational level of knowledge regarding SMS. Additionally, the data suggests a strong overall competency in SMS among the surveyed safety officers, although there is still room for improvement.

Table 1
Safety Officer Knowledge of SMS

Degree of SMS Familiarity	n
No Knowledge	0
Some Knowledge	3
Knowledgeable	8
Very Knowledgeable	7
SMS Expert	3

The participants described the degree of SMS development and implementation at their respective institutions. Their responses to this survey question are shown in Table 2. When the surveys were submitted, six respondents (28.57%) indicated they had fully implemented SMS. Nearly half of the sample population (n = 9, 42.9%) had not yet fully incorporated SMS into their pilot training programs, and six (28.57%) participants were not using SMS to manage their safety programs at all. The results suggest that some institutions may encounter challenges in adopting SMS. Furthermore, the number of participants who do not use SMS at all indicates potential gaps in safety management practices. Overall, the data highlights a need for increased support and training to promote full SMS adoption by Part 141 institutions.

Table 2
SMS Involvement

Degree of SMS Development/Implementation	n
SMS is Not Under Development	6
SMS is Under Development	7
Some SMS components functional	2
SMS is Fully Implemented	6

The final question regarding SMS demographics prompted the survey respondents to forecast when their organization intended to fully implement SMS. Table 3 displays the anticipated timeframe of when the organizations planned to implement an SMS and have an SMS fully in place. Six (28.57%) of the organizations did not answer the question since they already had a fully functional SMS. Only four (19.0%) participants indicated that their institutions would fully implement SMS within a year of the survey. The data highlights the variance in adoption rates between institutions.

Table 3
Projected SMS Implementation

Number of Years Until Full SMS	n
Unsure	4
Within 1 year	4
Within 2 to 3 Years	2
More than 3 Years	5
Did Not Answer	6

Part 2 - Management Commitment

The second section of the survey sought to evaluate the dedication of managers within the participating pilot training schools toward SMS. The level of management commitment was measured by evaluating various management activities related to SMS and soliciting feedback from the survey respondents to assess the level of commitment to SMS demonstrated by their managers.

SMS-related Activities

Survey respondents were asked to select applicable items from a list of actions meant to represent an institution's commitment to safety in the context of SMS. Table 4 illustrates the breakdown of the different SMS activities utilized by respondents in their IHEs. Because the survey had 21 respondents, each activity had a maximum participation level (n) of 21. Based on the responses, most research participants used all listed SMS activities. Investments in human and financial resources (n = 17, 72%) received the fewest responses in this category. These results are nearly identical to the Roberston et al. (2017) study, showing that management commitment among the surveyed IHEs remained strong and relatively unchanged. However, the need for additional human and financial resource investments remained an issue.

Table 4
Activities that Represent Management Commitment to SMS

SMS Activity	n
Invests human and financial resources	17
Proactive in preventing accidents	20
Consistently enforces safety procedures	20
Views regulatory violations seriously	21
Involved in safety activities	20

Management's Commitment to Implement SMS

The safety officers who participated in the survey assessed their managers' commitment to implementing SMS at their institution using a rating scale ranging from 0 to 10, with 0 representing no commitment and 10 representing total commitment. The question received 21 responses, with the mean response being 7.1 on a 0 to 10 scale and a standard deviation of 2.7. These results indicate that, on average, safety officers believed their respective managers were strongly committed to implementing SMS at their institutions. Furthermore, these results are relatively unchanged compared to those of Robertson et al. (2017).

Part 3 - SMS Implementation

The final section of the survey intended to assess the extent to which SMS is put into practice within the participating institutions. The assessment relied on the framework provided by the four components of SMS and their associated elements. An evaluation was conducted to measure the degree of SMS implementation of the various components and elements of SMS used at the participating schools.

Safety Policy

In the survey's safety policy section, respondents were prompted to identify the elements associated with the safety policy they incorporated into their safety programs. The results of this question are displayed in Table 5. Twenty of the 21 respondents (95%) indicated they had developed a safety policy statement, and 19 (90%) indicated they had identified a safety committee. Developing an implementation plan was the least common, with seven replies (33%) indicating a possible gap between policy creation and execution. The percentage of overall implementation of the safety policy component across the participating pilot training schools is 73.81%.

Table 5
Safety Policy Implementation

Safety Policy Activity/Process	n
Completed gap analysis	9
Developed an implementation plan	7
Developed a safety policy statement	20
Developed a set of SMS objectives	18
Identified an accountable executive	17
Identified an SMS manager/coordinator	17
Identified a safety committee	19
Developed an emergency response plan	17
Total Safety Policy Implementation Score	73.81%

Safety Risk Management

This section asked respondents to examine their SMS and identify which elements and processes related to SMS they had established at their respective institutions. The results of this inquiry are displayed in Table 6. Of the 21 participants, 19 (90.48%) had established a method or methods for identifying hazards, and 18 (85.71%) of the respondents indicated that they tracked and documented hazards. Only eight (38.10%) respondents reported having a formalized 5-step SRM process at their institution, highlighting a significant gap in the formal implementation of the complete 5-step SRM process. The overall SRM implementation score across the pilot training programs is 72.45%, suggesting that foundational SRM processes are in place but with room for improvement.

Table 6
SRM Implementation

SRM Activity/Process	n
Hazard Identification	19
Hazard Tracking and Documentation	18
Risk Analysis	16
5-step SRM Process	8
Safety Risk Assessment	15
Total SRM Implementation Score	72.45%

Safety Assurance

The next question evaluated the extent of safety assurance activities implemented at the participating institutions. To accomplish this, survey respondents identified which elements and processes they had in place regarding the safety assurance component. Table 7 illustrates the outcomes of this inquiry and the implementation score for the safety assurance component.

Table 7
Safety Assurance Implementation

Safety Assurance Activity/Process	n
Confidential Hazard Reporting System - Paper	6
Confidential Hazard Reporting System - Web	19
Trend Analysis Capability	13
Safety Performance Monitoring	10
Continuous monitoring of Safety Controls	9
Flight Data Monitoring Analysis	13
SMS Audits/Evaluations	8
Safety Culture Assessments	14
Total Safety Assurance Implementation Score	54.77%

Twenty (95.24%) of the 21 respondents indicated that they had a confidential hazard reporting system. The safety assurance elements are implemented in approximately 55% of the pilot training schools that responded, compared to approximately 44% observed by Robertson et al. (2017). The relatively low overall implementation rate of safety assurance elements (55%) suggests that while hazard reporting is widely adopted, other critical aspects of safety assurance may be lacking. The safety assurance activities with the lowest response rates included continuous monitoring of safety controls, SMS audits, and paper hazard reporting systems. Paper reporting systems appear redundant in most cases, as 19 of the 21 respondents indicated using a web-based hazard reporting system. Continuous monitoring of safety controls and SMS audits requires significant time commitment for safety personnel, which likely contributed to their lower response rates.

Safety Promotion

The next component evaluated in this research is the implementation of safety promotion activities. The results of this survey question are displayed in Table 8. Seventeen (81%) respondents indicated that they held employee safety meetings. However, only seven (33%) reported having regularly scheduled SMS training for their employees. According to the results, safety stand-downs are utilized by twelve (57%) respondents, and nine out of those twelve (75%) indicated that they hold regular safety meetings for both students and employees. A safety stand-down typically involves pausing operations for safety-related training. The data suggests that while safety promotion activities were present, their implementation was inconsistent across the participating institutions. There appears to be a strong focus on communication but a significant gap in ongoing training. The somewhat low implementation rate of 49.73% across the sample of pilot training programs illustrates that there is substantial room for improvement in fully integrating safety promotion efforts.

Table 8
Safety Promotion Implementation

Safety Promotion Activity/Process	n
Specialized SMS Training	7
Regular SMS training – Employees	7
Regular SMS training – Students	4
Safety bulletin boards	12
Safety newsletters	12
Employee safety meetings	17
Student safety meetings	15
Safety awards program	8
Safety stand-downs	12
Total Safety Promotion Implementation Score	49.73%

Fatigue Risk Management System

The last component assessed for this research is the implementation of FRMS activities. The results of this survey question are displayed in Table 9. Fourteen (67%) of the respondents indicated that they monitor the flight duty period for instructors, while ten (48%) reported monitoring the flight duty period for students. The discrepancy between monitoring instructors' flight duty periods (67%) and doing the same for students (48%) suggests inconsistencies in fatigue management practices. Only nine (43%) respondents indicated using a flight risk assessment tool (FRAT). Additionally, six (29%) respondents provided fatigue awareness training, and four (19%) promoted fatigue awareness. None of the respondents indicated that they collected sleep data from either students or instructors.

Overall, the results suggest that FRMS activities are absent in most of the respondents' flight training schools, with an implementation rate of only 19.36%. This overall implementation rate indicates that FRMS activities are significantly lacking among the participating institutions. Furthermore, the low adoption of some FRMS components, such as using a FRAT or collecting sleep data, highlights gaps in proactive fatigue mitigation. Note that FRMS is relatively new compared to SMS, which is likely contributing to its low implementation rate. The low adoption rate could also be attributed to safety officers lacking the additional resources needed to develop and maintain an FRMS in addition to their existing SMS. Regardless, the significant lack of FRMS activities supports the need for further research.

Table 9
FRMS Implementation

FRMS Activity/Process	n
Fatigue Safety Action Group	2
FRMS Policy	2
FRMS Objectives	1
Fatigue Specific Reporting System	1
Process to Identify Fatigue Hazards and Risks	5
Utilize HFACS	5
Flight Risk Assessment Tool (FRAT)	9
FRMS Safety Performance Indicators	1
FRMS Documentation	1
Fatigue Awareness Training	6
Fatigue Awareness Promotion	4
Flight Duty Period for Students	10
Flight Duty Period for Instructors	14
Collect Sleep Data on Students	0
Collect Sleep Data on Instructors	0
Total FRMS Implementation Score	19.36%

Discussion

Research Question 1

The primary demographic information of the participating pilot training schools was determined through the first question. The participants rated their knowledge of SMS, the results of which are listed in Table 10. The number of respondents (n = 21) for the current study was lower than the number of respondents (n = 28) for the original study by Robertson et al. (2017). The percentage of respondents who reported their SMS familiarity as knowledgeable or better remains unchanged from the original study of Robertson et al. (2017), at 85.71% (n = 18). All respondents in the current survey and the Roberston et al. (2017) study indicated having some knowledge of SMS. Additionally,14% (n = 3) of respondents identified as an "SMS Expert" in the current study, compared to 0% of respondents claiming to be experts in 2017. While the percentage of fully implemented SMS increased by approximately 11%, with 28.57% (n = 6) currently reporting their SMS involvement as "SMS is Fully Implemented" compared to 17.86% (n = 5) in 2017, this change appears to be negligible, and due to a shift in sample size.

The data suggests that knowledge of SMS among participants has remained consistent since the original study by Robertson et al. (2017), with more participants (14%) identifying as “SMS Experts” compared to none in the 2017 study. However, the overall increase in fully implemented SMS programs is relatively low and may be attributed to the smaller sample size as opposed to significant improvements across the participant institutions. The data indicates that although there has been some growth in SMS knowledge and implementation, the growth rate remains slow, and further efforts may be needed to increase SMS adoption across Part 141 institutions.

Table 10
Safety Officer Knowledge of SMS

Degree of SMS Familiarity	Previous		Current	
	n	%	n	%
No Knowledge	0	0.00%	0	0.00%
Some Knowledge	4	14.29%	3	14.29%
Knowledgeable	11	39.29%	8	38.10%
Very Knowledgeable	13	46.43%	7	33.33%
SMS Expert	0	0.00%	3	14.26%
Total	28		21	

Table 11 shows that the percentage of respondents not developing SMS and appearing to have no intention to start has remained relatively unchanged since 2017. Twenty-one percent (*n* = 6) of respondents in 2017 responded "N/A" when asked about a timeline for SMS implementation. If we adjust that number to exclude those that had fully implemented SMS in 2017, that percentage drops to 14% (*n* = 4). The current survey shows 19% of respondents (*n* = 4) as "Unsure" about their timeline to implement SMS. The response seems to confirm the reluctance to change in institutional safety programs noted by Roberston et al. in 2017. Of the four who indicated "Unsure" in the current survey, all (100%) reported their SMS knowledge as "Knowledgeable" or greater. Therefore, the participants who responded "Unsure" when asked about SMS implementation timelines appear to have the knowledge needed to implement an SMS. Although there are many reasons why an organization chooses not to transition their safety program to an SMS, the survey results suggest that lack of knowledge, at least among this sample, is not one of them. The findings reinforce the conclusions of Robertson et al. (2017) regarding the hesitancy of institutions to modify their existing safety programs despite having the necessary knowledge to do so.

Table 11
SMS Involvement

Degree of SMS Development/Implementation	Previous		Current	
	n	%	n	%
SMS is Not Under Development	6	21.43%	6	28.57%
SMS is Under Development	9	32.14%	7	33.33%
Some SMS components functional	8	28.57%	2	9.52%
SMS is Fully Implemented	5	17.86%	6	28.57%
Total	28		21	

Regarding the four respondents who selected "Unsure" when asked about projected SMS implementation timelines, 75% (n = 3) contracted their flight training to a third party. Similarly, 75% (n = 3) of respondents who reported using third-party flight training and did not already have SMS in place (n = 4) also indicated being "Unsure" about the timeline for SMS implementation. Of the five respondents with third-party contractors providing flight training, only one (20%) reported having a fully implemented SMS. Conversely, 83% (n = 5) of respondents who indicated having a fully implemented SMS do not use third-party contractors for their flight training.

Table 12
Projected SMS Implementation

Number of Years Until Full SMS	Previous		Current	
	n	%	n	%
Not Applicable/Unsure	9	32.14%	4	19.05%
Within 1 year	8	28.57%	4	19.05%
Within 2 to 3 Years	9	32.14%	2	9.52%
More than 3 Years	1	3.57%	5	23.81%
Did Not Answer	1	3.57%	6	28.57%
Total	28		21	

Research Question 2

The survey's second section pertains to management's commitment to implementing SMS programs within their respective institutions. All respondents (n = 21) indicated that management views regulatory violations seriously, a slight increase from the previous study. In addition, 95% (n = 20) of respondents reported that management was proactive in preventing accidents, consistently enforcing safety procedures, and being involved with safety activities. These results indicate the participating institutions' high level of engagement in safety culture. However, the slightly lower response (81%, n = 17) regarding investments in human and financial resources suggests that while management prioritizes SMS, there may still be challenges in fully supporting successful implementation.

Table 13
SMS Activities at Pilot Training Schools

SMS Activity	Previous		Current	
	n	%	n	%
Invests human and financial resources	19	67.86%	17	80.95%
Proactive in preventing accidents	25	89.29%	20	95.24%
Consistently enforces safety procedures	24	85.71%	20	95.24%
Views regulatory violations seriously	26	92.86%	21	100.00%
Involved in safety activities	24	85.71%	20	95.24%
Total	28		21	

The survey data in Table 13 follows the same trend observed in the previous study by Robertson et al. (2017), which indicates that flight training institutions seem concerned with things that affect their financial standing, such as regulatory violations and accidents. At the same time, the lowest level of commitment by members of management (See Tables 4 and 13) was "Invests in human and fiscal resources."

Other forms of financial commitment were observed when looking at safety program elements. Employee safety meetings had the highest participation of all responses (81%, n = 17) when asked about safety promotion. While this option does not represent a substantial financial commitment, a safety meeting is a non-revenue activity and, by extension, represents some financial commitment. By contrast, other safety promotions with a more noticeable impact on finances received lower response rates, such as safety stand downs (n = 12) and specialized training for safety staff (n = 7). The results shown in Table 13 indicate that management is highly committed to implementing and overseeing SMS programs, which are mainly proactive, compared to traditional safety programs, which are typically reactive. Still, continued investment of resources could further strengthen SMS activities.

Research Question 3

SMS comprises four components: safety policy, safety risk management (SRM), safety assurance, and safety promotion. The third section of the study assesses how and to what degree the participating institutions are implementing each component.

Safety Policy

The safety policy implementation score, shown in Table 14, increased from 64.73% in the previous study to 73.89% in the present study. "Identifying a safety committee" had the most significant increase in implementation, from 57% (n = 16) in the previous study to 90% (n = 19) in the current study. In contrast, a 5% decrease from the previous study in the number of flight training programs that identified an SMS manager or coordinator was observed. The decrease may indicate that flight training programs rely more on committees to manage their SMS systems than a single manager or coordinator.

The number of flight training programs reporting they had developed a set of SMS objectives had a significant 22% increase. The increase may be due to the length of time that SMS has been implemented. In the previous study, 64% (*n* = 18) of respondents indicated they were more than one year away from full SMS implementation, while only 52% (*n* = 11) of present respondents indicated the same time frame. The increased number of schools with fully implemented SMS programs supports the increased implementation score for the safety policy component.

The number of respondents who indicated they had "Developed an implementation plan" dropped from 50% (*n* = 14) previously to 33% (*n* = 7) currently. While this comparison appears concerning, a deeper dive into the data reveals little change. Of the 14 who did not indicate the presence of an implementation plan in the current study, (a) two indicated that they already had a fully implemented SMS, (b) two indicated transitioning to an SMS, with some SMS components functional, (c) five indicated currently having a safety program, and SMS was under development, and (d) five indicated the presence of a safety program, and SMS was not under development. Suppose the presence of an implementation plan is assumed for those respondents who indicated that they currently have a fully implemented SMS. In that case, the percentage of respondents who have or had an implementation plan at one point due to having already implemented SMS rises to 42.86% (*n* = 9) compared to 50% (*n* = 14) in the previous study. Overall, the data indicates continued advancement in SMS adoption at Part 141 programs, with more institutions embracing structured safety policies and objectives.

Table 14
Safety Policy Implementation

Safety Policy Activity/Process	Previous		Current	
	n	%	n	%
Completed gap analysis	8	28.57%	9	42.86%
Developed an implementation plan	14	50.00%	7	33.33%
Developed a safety policy statement	22	78.57%	20	95.24%
Developed a set of SMS objectives	18	64.29%	18	85.71%
Identified an accountable executive	19	67.86%	17	80.95%
Identified an SMS manager/coordinator	24	85.71%	17	80.95%
Identified a safety committee	16	57.14%	19	90.48%
Developed an emergency response plan	24	85.71%	17	80.95%
Total Safety Policy Implementation Score	28	64.73%	21	73.81%

Safety Risk Management

The SRM component of SMS experienced the most significant increase in implementation, rising from 57.86% in the previous study to the present implementation score of 72.45%, as shown in Table 15. Highlighting a substantial improvement in implementation. Among the various elements of SRM, hazard tracking and documentation saw the most significant increase, from 64% (*n* = 18) in the previous study to 86% (*n* = 18) in the current study. The safety risk assessment element saw a similar increase, from 50% (*n* = 14) in 2017 to 71% (*n* = 15) in the present data, suggesting that more institutions are incorporating structured processes for evaluating risks. Overall, the data indicates a move to a more proactive SRM system.

The notable increase in Hazard Tracking and Documentation appears to be the most significant among the SRM components. As noted in the previous study by Roberson et al. (2017), only 75% (*n* = 18) of those respondents who practiced hazard identification reported tracking and documenting those hazard trends over time. In the current study, 94% (*n* = 18) of those who practiced hazard identification (*n* = 19) tracked and documented that information to identify hazard trends. Considering that trend analysis is one of the last stages in safety risk management (Robertson et al., 2017), this increase identifies significant progress in developing and implementing SRM in collegiate flight schools. The data indicates that pilot training programs are moving beyond basic hazard identification toward more comprehensive risk management practices, reflecting a strong safety culture and a more data-driven approach to mitigating risks.

Table 15
SRM Implementation

SRM Activity/Process	Previous		Current	
	n	%	n	%
Hazard Identification	24	85.71%	19	90.48%
Hazard Tracking and Documentation	18	64.28%	18	85.71%
Risk Analysis	19	67.86%	16	76.19%
5-step SRM Process	6	21.43%	8	38.10%
Safety Risk Assessment	14	50.00%	15	71.43%
Total SRM Implementation Score	28	57.86%	21	72.45%

Safety Assurance

Overall, the safety assurance component of SMS saw a conservative increase in implementation score from 44.20% in 2017 to 54.77%, as shown in Table 16. The most significant increase and decrease were related to the transition from paper-based confidential hazard reporting systems to digital-based systems. In both studies, nearly all respondents had a confidential reporting system in place. Only 54% (*n* = 15) of respondents utilized digital reporting systems in 2017 compared to 90% (*n* = 19) in the current study. In contrast, 57% (*n* = 16) of respondents in the 2017 study indicated using paper-based systems compared to 29% (*n* =

6) in 2023. With web-based applications increasing in popularity and ease of access, future studies may show a continued shift from paper to web-based reporting systems.

Flight data monitoring (FDM) analysis increased notably from 29% (*n* = 8) in 2017 to 62% (*n* = 13) in the present data. The increase shows a commitment to increasing safety within the represented flight training programs. Possible reasons for the increase could include increased use of fully integrated digital cockpit displays, more widespread knowledge of these systems' capabilities, or increased interest after seeing what early adopters have done with data. The processes involved in safety assurance, particularly those involving monitoring and analysis, are often the last ones to be implemented. It is also important to note that the FDM analysis takes time, skilled personnel, and resources. The fact that such a substantial increase in FDM analysis was observed is highly encouraging. Further research is needed to determine how different institutions utilize their FDM findings regarding policies and operations.

The implementation percentage for continuous monitoring of safety controls remained unchanged between the two studies. In 2017, 42.86% (*n* = 12) reported implementing continuous monitoring of safety controls compared to 42.89% (*n* = 9) in the present study. The lack of increase could indicate challenges in maintaining long-term oversight processes, possibly due to resource constraints or a lack of standardized procedures. While progress has been made, there is still room for improvement in fully integrating safety assurance components across Part 141 programs.

Table 16
Safety Assurance Implementation

Safety Assurance Activity/Process	Previous		Current	
	n	%	n	%
Confidential Hazard Reporting System - Paper	16	57.14%	6	28.57%
Confidential Hazard Reporting System - Web	15	53.57%	19	90.48%
Trend Analysis Capability	14	50.00%	13	61.90%
Safety Performance Monitoring	9	32.14%	10	47.62%
Continuous monitoring of Safety Controls	12	42.86%	9	42.86%
Flight Data Monitoring Analysis	8	28.57%	13	61.90%
SMS Audits/Evaluations	7	25.00%	8	38.01%
Safety Culture Assessments	18	62.29%	14	66.67%
Total Safety Assurance Implementation Score	28	44.20%	21	54.77%

Safety Promotion

The implementation score for the safety promotion component of SMS, shown in Table 17, remained nearly the same between the two studies, with 48.02% in 2017 and 49.73% in 2023. The reported use of safety stand-downs increased significantly from 36% (*n* = 10) in 2017 to 57% (*n* = 12) in the present study, indicating a possible stronger emphasis on temporarily pausing operations for dedicated safety training. The use of safety bulletin boards declined by

25% between 2017 and 2023. Similarly, regular SMS training for students decreased from 39% (n = 11) in 2017 to 19% (n = 4) in 2023. These declines raise concerns, suggesting a shift away from traditional forms of communication and structured SMS training. The only other component with significant change is safety newsletters, with 39% (n = 11) reporting using safety newsletters in 2017 compared to 57% (n = 12) in 2023. The data indicates that institutions may be relying more on structured, periodic safety communication.

Similarly, a shift from paper reporting systems to web-based reporting systems was observed, but a shift from safety bulletin boards is notable. While it might be tempting to infer an increase in analog promotion methods when noting the increased use of safety newsletters, as of this writing, a newsletter is likely. Further research is needed to determine if modern social media applications like Instagram are replacing promotional tools like bulletin boards. The effectiveness of social media and short video format content as a safety promotion tool for higher education aviation institutions is also worthy of further study.

Table 17
Safety Promotion Implementation

Safety Promotion Activity/Process	Previous		Current	
	n	%	n	%
Specialized SMS Training	10	35.71%	7	33.33%
Regular SMS training – Employees	8	28.57%	7	33.33%
Regular SMS training – Students	11	39.29%	4	19.05%
Safety bulletin boards	23	82.14%	12	57.14%
Safety newsletters	11	39.29%	12	57.14%
Employee safety meetings	25	89.29%	17	80.95%
Student safety meetings	19	67.86%	15	71.43%
Safety awards program	4	14.29%	8	38.10%
Safety stand-downs	10	35.71%	12	57.14%
Total Safety Promotion Implementation Score	28	48.02%	21	49.73%

Table 18
Fatigue Risk Management Implementation

Fatigue Risk Management Systems	Current	
	n	%
Fatigue safety action group	2	9.52%
FRMS policy	2	9.52%
FRMS objectives	1	4.76%
Fatigue specific reporting system	1	4.76%
Process to identify fatigue hazards and risks	5	23.81%
Utilize human factors analysis and classification system (HFACS)	5	23.81%
Flight risk assessment tool (FRAT)	9	42.86%
FRMS safety performance indicators	1	4.76%
FRMS documentation	1	4.76%
Fatigue awareness training	6	28.57%
Fatigue awareness promotion	4	19.05%
Flight duty period for students	10	47.62%
Flight duty period for instructors	14	66.67%
Collect sleep data on students	0	0.00%
Collect sleep data on instructors	0	0.00%
Other (please specify)	1	4.76%
Total Safety Promotion Implementation Score	21	18.45%

Research Question 4

Table 18 displays the results for the final section of the survey that evaluated the implementation of FRMS in collegiate flight training schools. The previous study by Robertson et al. (2017) did not assess FRMS as the concept was relatively new then; thus, there are no previous results to compare. The following is a descriptive report of the status of FRMS implementation as reported by the participants.

The overall implementation score of FRMS at 18.45% was relatively low compared to the SMS implementation scores, indicating that the implementation of FRMS is still in its early stages. The highest implementation scores were for flight duty periods for students (n = 10, 47.62%) and instructors (n = 14, 66.67%). Flight duty periods typically include policies directing rest periods and documentation of time worked, thereby making them easier to implement and manage. None of the respondents indicated that they collect sleep data for students or instructors. One institution (4.76%) marked "other," specifying they emphasized fatigue during instructor/pilot and student safety meetings.

One of the highest implementation scores was for the FRAT at 42.86% (n = 9). A FRAT is relatively easy to implement and does not bring a significant fiscal impact, which may account for the higher implementation score. While the use of FRATs was not assessed by Roberton et al. (2017), it is worth noting that the concept of a FRAT predates FRMS. FRATs are not exclusively

FRMS tools but have their roots in SMS. The FAA discusses the concept of a FRAT as early as 2007 in their Information for Operators (InFO) publication (FAA, 2007). InFO 07015 states the importance of a FRAT as an SMS tool. Given that FRATs predate the prevalence of FRMS, the high percentage of FRAT implementation compared to other tools is understandable.

Overall, while some components of FRMS, such as flight duty period tracking and FRAT use, are being implemented, other strategies, such as sleep data collection, are lacking. Considering that collegiate flight students tend to have poor sleep quality and irregular sleep schedules, the low adoption of FRMS is concerning (Romero et al., 2020). With 95% of collegiate flight students and instructors reporting that fatigue has negatively impacted their flight training, the need for more significant institutional commitment to FRMS development through potential policy changes, training, and increased awareness of fatigue-related risks in flight training environments is critical to ensure safe operations (Keller et al., 2022; McDale & Ma, 2008; Romero et al., 2020).

Future Research

The SMS and FRMS data reported in this study are descriptive and represent a snapshot of implementation during 2021-2022. Therefore, a follow-up study should be conducted in three to five years to generate comparative data on SMS and FRMS implementation utilizing an updated classification system to correspond with the current SMS AC 120-92D and FRMS AC 120-103A. Considering that some Part 141 programs contract out their flight training to third-party providers, it is recommended that a separate study be conducted to identify barriers to implementing SMS and FRMS among these specific institutions. Additionally, exploring Part 141 institutional factors such as financial constraints, policy challenges, and administrative resistance may help identify barriers to SMS and FRMS implementation and thus help identify potential solutions.

Although SMS and FRMS are closely related, the FAA continues to treat them as separate systems. Future research should investigate potential impacts on the effectiveness of SMS and FRMS if they were treated as a single system. Furthermore, additional research should evaluate the implementation of FRMS elements listed in ICAO Doc 9966 that were not assessed in this study.

Conclusion

Considering the data, it can be concluded that college flight programs are doing well with SMS implementation. Overall, knowledge of SMS has increased among the management of college flight programs. Participants reporting as "knowledgeable" of SMS increased from 2017 to the current study. Additionally, the SRM implementation score increased by over 15%. Further, safety policy and safety assurance implementation scores increased by approximately 10% each, while safety promotion implementation remained relatively unchanged. Overall, most components' scores increased or remained unchanged, demonstrating a solid commitment to safety. Conversely, the FRMS implementation score was relatively low at 18.45% compared to SMS implementation scores. The difference in implementation rates between the two systems may be due to FRMS being created after SMS. The fact that the FAA treats SMS and FRMS as two independent systems is also a possible reason for low FRMS implementation rates.

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Appendix A

Table A1
SMS Components and Related Elements

Safety Policy	Safety Risk Management	Safety Promotion	Safety Assurance
• Completed gap analysis • Implementation plan • Safety policy statement • SMS objectives • Identified accountable executive • Identified SMS manager/coordinator • Identified safety committee • Emergency planning and response	• Hazard identification • Hazard tracking and documentation • Risk analysis • 5-Step SRM process • Conducted safety risk assessments	• Specialized SMS training • Regular SMS training – Employees • Regular SMS training – Students • Safety bulletin boards • Safety newsletters • Employee safety meetings • Student safety meetings • Safety awards program • Safety stand-downs	• Confidential hazard reporting system – Web • Confidential hazard reporting system – Paper • Trend analysis • Safety performance monitoring • Continuous monitoring of safety controls • Flight data monitoring analysis • SMS audits or evaluations • Safety culture assessments

Table A2
FRMS Components and Related Elements

Policy and Documentation	FRMS Processes	Promotion Processes	Safety Assurance
• Policy • Objectives • Flight Duty Periods • Creating a Fatigue Safety Action Group	• Identification of hazards • Risk Assessment • Use of HFACS	• Training programs	• Fatigue Specific Reporting System • FRMS performance monitoring

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Continual Learning Models in Aviation Systems

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This paper explores the vital role of continual lifelong learning in advancing machine learning applications within the aviation industry. Through case studies on predictive maintenance and adaptive flight routing, we demonstrate how human-inspired continual learning enables AI systems to adapt incrementally to evolving conditions while preserving critical prior knowledge. This approach addresses fundamental challenges in dynamic, safety-critical aviation environments, promising improved adaptability, safety, and operational efficiency. The discussion highlights benefits, challenges, current progress, and future directions toward building resilient, intelligent aviation AI systems.

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Introduction

In safety-critical industries such as aviation, machine learning (ML) systems are increasingly being adopted to support and automate complex tasks, from predictive maintenance and real-time flight routing to intelligent crew scheduling and autonomous systems. While conventional ML models have achieved impressive performance under fixed conditions, they typically suffer from a significant limitation: the inability to learn continuously after deployment. Once trained, these systems are rarely designed to adapt to new tasks or data distributions without retraining from scratch. This static learning paradigm is ill-suited to the dynamic nature of the aviation domain, where regulatory frameworks, environmental variables, operational procedures, and technological platforms are in constant flux.

To address this challenge, researchers are turning to human-inspired learning paradigms, particularly continual lifelong learning (Parisi et al., 2019). This approach seeks to equip artificial agents with the ability to learn incrementally, adapt to novel tasks, and refine prior knowledge without experiencing catastrophic forgetting (Barari & Kim, 2021). Continual lifelong learning reflects a key trait of human cognition: the ability to accumulate experience over a lifetime while flexibly incorporating new information (Barari, Lian, & MacLellan, 2024a). In aviation, this capability is essential for ensuring that intelligent systems remain effective as they encounter new aircraft platforms, operational theaters, or emergent failure modes (Barari, Lian, & MacLellan, 2024b).

Central to the design of continual learning systems is the management of the plasticity-stability trade-off. On one hand, plasticity allows a model to integrate new information; on the other, stability ensures that valuable prior knowledge is retained. A system biased too heavily toward plasticity risks overwriting past experience, potentially degrading performance in previously learned domains. Conversely, excessive stability may hinder the model's capacity to adapt, rendering it inflexible in the face of change.

Continual learning models can also contribute to enhanced learner engagement by enabling systems that adapt dynamically to evolving learner behavior and performance. As these models accumulate knowledge over time, they support more personalized and responsive educational experiences (Barari & Sanders, 2024).

To explore how continual learning can be practically implemented in aviation, we build on foundational theory and illustrate two aviation-specific case studies in the following sections. These case studies highlight how continual learning methods address critical challenges in dynamic, safety-critical environments.

Literature Review

The field of Continual Learning, also known as lifelong learning, has emerged in recent years as a response to the limitations of traditional machine learning models, which are generally trained offline on fixed datasets and assume stationary environments. In contrast, continual learning seeks to emulate the incremental and adaptive nature of human cognition, allowing models to learn from a sequence of tasks without experiencing catastrophic forgetting, a phenomenon in which new learning overwrites previously acquired knowledge (McCloskey & Cohen, 1989).

The issue of catastrophic forgetting was identified early in connectionist models and remains a core challenge in neural networks trained sequentially (Czigler & Winkler, 2010). A model optimized on new data tends to overwrite weights critical to past tasks unless explicitly constrained. Addressing this requires managing the stability-plasticity trade-off: stability ensures retention of old knowledge, while plasticity allows adaptation to new data. Several algorithmic families have emerged to handle this trade-off:

- Regularization-based methods (e.g., Elastic Weight Consolidation) penalize changes to important parameters (Kirkpatrick et al., 2017).
- Replay-based methods store or generate past data to interleave with new training (e.g., Deep Generative Replay, (Shin et al., 2017)).
- Dynamic architectural methods like Progressive Neural Networks (Rusu et al., 2016) expand model capacity with task-specific modules.

Among these, Elastic Weight Consolidation (EWC) has been widely studied and adopted for its simplicity and biological plausibility. It approximates the Fisher Information Matrix (FIM) (Fisher, 1987) to estimate parameter importance and regularizes the loss function to resist changes to critical weights. This method is particularly suited for applications where task boundaries are clear and domain shifts are significant yet structured (Fisher, 1996).

Most continual learning research has focused on benchmark datasets (e.g., Permuted MNIST, Split CIFAR-100), which are designed as academic tools to evaluate a model’s ability to avoid catastrophic forgetting in controlled settings. While these datasets are not representative of aviation data, they provide a standardized basis for testing continual learning algorithms before application in real-world domains such as aviation. The growing interest in applying these techniques to real-world, safety-critical domains is now evident, especially in robotics, autonomous vehicles, and aerospace. These fields demand adaptive systems that can update incrementally without complete retraining, while maintaining robustness and trustworthiness.

In the aviation domain, continual learning remains underexplored but highly promising. Aircraft systems evolve over time through new engine types, avionics upgrades, and environmental or regulatory shifts. Each change introduces new "tasks" to which intelligent systems must adapt. This is especially relevant for predictive maintenance, where engine performance and failure patterns differ between models but share underlying principles.

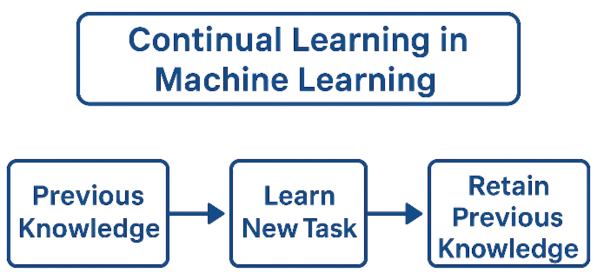
The following sections present aviation-specific examples that illustrate how continual learning can enhance reliability and adaptability in real-world applications. Each case explores how the plasticity-stability trade-off manifests and how it may be mitigated using mechanisms drawn from both neuroscience and contemporary machine learning research.

Theoretical Framework

This work adopts a conceptual case study methodology to explore how continual learning techniques, such as Elastic Weight Consolidation and experience replay, might be applied in real-world aviation scenarios. While we do not present empirical results or formal simulations, the use of theoretical case studies allows us to map established machine learning techniques onto aviation-specific challenges in a structured and illustrative manner. This approach enables early-stage exploration of feasibility, trade-offs, and potential impact. Further validation through implementation, simulation, or field studies will be essential to confirm these findings and guide operational adoption.

As mentioned, the concept of continual lifelong learning emerges from the need to construct machine learning systems that can learn in a manner similar to human cognition, incrementally, adaptively, and without forgetting prior knowledge. Unlike conventional models, which are trained on static datasets and deployed with fixed capabilities, continual learning systems evolve over time. They integrate new information from sequential tasks or data streams while preserving competencies from earlier experiences. This paradigm is essential for building intelligent systems capable of functioning in dynamic, real-world environments such as aviation. A simplified continual learning is illustrated in Figure 1.

Figure 1
Simplified Continual Learning



The theoretical foundations of continual learning are deeply rooted in the stability-plasticity dilemma. Plasticity refers to a model's capacity to acquire new knowledge, whereas stability denotes the ability to retain previously learned information. A system overly biased toward plasticity may suffer from catastrophic forgetting, where new learning disrupts older knowledge. Conversely, a system that is too stable becomes rigid and unable to adapt to new challenges. Effective continual learning involves balancing these forces, ensuring long-term retention of critical skills while enabling flexibility in acquiring new ones.
In the context of aviation, the theoretical constructs are not only intellectually compelling but also practically necessary. Aviation systems operate in non-stationary environments: aircraft fleets evolve, airspace regulations shift, mission parameters change, and sensor technologies advance. AI systems that support maintenance diagnostics, route planning, or autonomous control must therefore learn over time without degrading performance on previously mastered domains.

The objective of integrating continual learning into aviation applications is to enable robust, flexible, and trustworthy AI systems that improve with experience, mirroring the way human experts build domain knowledge. This theoretical framework informs the two case studies that follow. In each, we examine a specific aviation use case where continual learning is applied to real operational challenges:

- The first case explores how EWC can support multi-fleet engine diagnostics, allowing a model to learn about new aircraft engines while preserving knowledge of legacy platforms.
- The second case investigates adaptive flight routing, where a routing model learns to operate effectively across geographically and regulatorily distinct airspaces.

By grounding these applications in continual learning theory, we discuss how conceptual advances in machine learning can directly address pressing needs in safety-critical, data-rich aviation environments.

Case Study 1: Continual Learning in Predictive Maintenance for Multi-Fleet Engine Diagnostics

One of the most promising applications of continual lifelong learning in aviation lies in the domain of predictive maintenance, where machine learning models are used to detect early signs of failure in aircraft engines. Airlines today operate increasingly diverse fleets composed of both legacy and next-generation aircraft, often from multiple manufacturers. As a result, maintenance AI systems must diagnose failures across engine types that differ in design, behavior, and sensor profiles.

Consider a scenario in which an ML-based health monitoring system is initially trained on CFM56 engines used in Boeing 737 aircraft. These engines generate large volumes of telemetry data, including vibration levels, exhaust gas temperature (EGT), fan speeds, and pressure ratios, which are used to build models for anomaly detection and Remaining Useful Life (RUL) estimation. Over time, the airline introduced a new fleet of Airbus A320neo aircraft equipped with LEAP-1A engines. The monitoring system must now learn to interpret and diagnose faults in LEAP-1A engines while retaining its existing diagnostic capabilities for the CFM56 fleet.

This transition highlights the need for continual learning. A naive retraining approach, where the model is updated using only LEAP-1A data, risks catastrophic forgetting, the loss of performance on previously learned CFM56 diagnostics (Kirkpatrick et al., 2017; Goodfellow, Bengio, & Courville, 2016). Conversely, retaining the original model without any adaptation to the new engine data results in suboptimal or even erroneous predictions for the LEAP-1A fleet.

Application of Elastic Weight Consolidation to Multi-Fleet Engine Diagnostics

To address the catastrophic forgetting problem inherent in sequential learning tasks, Elastic Weight Consolidation (EWC) offers an elegant solution grounded in neuroscientific principles. EWC allows the model to selectively remember important parameters learned from the original task while enabling flexibility to adapt to the new task.

The EWC approach modifies the training objective by introducing a regularization term that penalizes changes to model parameters deemed critical for prior tasks. This term is informed by the FIM, which quantifies the sensitivity of the loss function to each parameter. Parameters with a high FIM value are considered crucial for retaining previous knowledge, and thus deviations from their learned values are heavily penalized.

Formally, the EWC loss function is expressed as:

$$\mathcal{L}(\theta) = \mathcal{L}_{new}(\theta) + \sum_i \frac{\lambda}{2} F_i (\theta_i - \theta_i^*)^2$$

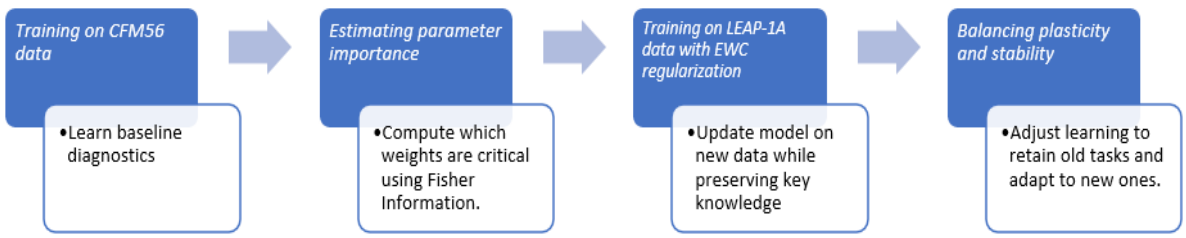
Where:

- $\mathcal{L}_{new}(\theta)$ represents the loss computed on the new dataset, here, the LEAP-1A engine telemetry.
- θ denotes the current parameter set of the diagnostic model.
- θ^* is the parameter set optimized on the prior task, specifically the CFM56 engine data.
- F_i are the diagonal elements of the FIM estimating the importance of each parameter θ_i for the CFM56 task.
- λ is a hyperparameter balancing the trade-off between learning new information and preserving old knowledge.

In the context of multi-fleet predictive maintenance, this approach entails the following steps (as shown in Figure 2):

1. *Training on CFM56 data:*
   The model is initially trained to converge on the CFM56 engine dataset, resulting in parameters θ^*. This training phase establishes baseline diagnostic capability on the legacy fleet.
2. *Estimating parameter importance:*
   The FIM is approximated by computing the expected squared gradient of the log-likelihood over the CFM56 data. This process identifies parameters essential to maintaining accurate diagnostics for the original fleet.
3. *Training on LEAP-1A data with EWC regularization:*
   When adapting the model to the new LEAP-1A data, the loss function is augmented by the EWC penalty term. This regularization discourages significant deviation of critical parameters from their previously learned values, effectively preventing the overwriting of CFM56 knowledge.
4. *Balancing plasticity and stability:*
   The hyperparameter λ regulates the balance between plasticity (the ability to learn new LEAP-1A patterns) and stability (retaining CFM56 performance). Careful tuning of λ is necessary, too low a value risks catastrophic forgetting, while too high a value can impede learning new tasks.

Figure 2
Multi-fleet Predictive Maintenance Steps



To implement this approach in practice, we follow a two-phase training loop that reflects the core structure of Elastic Weight Consolidation. The model is first trained on the legacy dataset (CFM56 engine telemetry), allowing it to learn baseline fault detection patterns. Once training on the initial task is complete, the FIM is estimated by computing the average squared gradients of the loss with respect to each model parameter. These gradients quantify the importance of each parameter in performing the original CFM56 task.

The second phase involves fine-tuning the model on the new task, fault prediction for LEAP-1A engines, using a modified loss function that incorporates the EWC regularization term. During this stage, the training loop calculates the new task loss while simultaneously penalizing updates that deviate from the previously learned and important parameters. The strength of this penalty is scaled by the corresponding FIM values and the regularization hyperparameter λ, which controls the balance between retaining legacy diagnostic capabilities and adapting to new engine behaviors.

A simplified pseudocode for this two-phase training procedure is provided within **Appendix A**, outlining the sequential steps of parameter initialization, importance estimation, and regularized fine-tuning. This framework allows predictive maintenance systems to evolve in sync with an expanding aircraft fleet, enabling high diagnostic accuracy across both legacy and emerging engine types without retraining from scratch.

By applying EWC in this way, the predictive maintenance system attains the capacity to learn continuously and adaptively across multiple engine types, supporting a heterogeneous fleet without the need for entirely separate models. This has the potential to reduce maintenance costs, improve fault detection reliability, and align with operational realities where fleets evolve over time.

This mechanism is directly inspired by human cognitive resilience: just as an experienced maintenance engineer draws on prior knowledge while assimilating new technical information, the model learns new engine behaviors without forgetting established diagnostic skills (Czigler & Winkler, 2010).

Case Study 2: Continual Learning in Adaptive Flight Routing Across Global Airspaces

An increasingly important application of machine learning in aviation is the optimization of flight routing in real time, especially in response to changing air traffic, regulatory constraints, and weather conditions. Traditionally, flight plans are generated before departure, with limited adaptability during flight. However, recent advancements in autonomous flight planning systems promise dynamic, onboard route optimization that enhances fuel efficiency, mitigates delays, and improves safety.

Consider an AI-based route optimization system originally trained on operations in North American airspace. This model is familiar with FAA routing structures, jet stream behavior across the Rockies, and regional weather patterns. When deployed in European airspace, the system encounters a different regulatory framework (e.g., Eurocontrol procedures), distinct weather systems (e.g., frequent fog in northern Europe), and denser, more variable airspace due to short-haul flights and temporary military zone activations.

For such a system to be operationally viable on a global scale, it must continually learn from regional data, adapting to new environments while preserving prior capabilities. This requires learning new weather-routing patterns and regulatory constraints without degrading performance in the original domain. A conventional retraining approach, in which the model is updated solely on European data, risks catastrophic forgetting of its North American routing expertise. Conversely, freezing the model to preserve U.S.-specific behaviors leads to rigidity, reducing performance in the new environment.

To strike a balance between adaptability and retention, continual learning techniques must address the plasticity-stability trade-off. In this context, plasticity allows the system to integrate knowledge about Eurocontrol vertical separation rules, active NOTAMs, and regional traffic patterns, while stability ensures that the model retains operational understanding of FAA altitude transitions, NAT (North Atlantic Tracks), and seasonal jet stream routing.

A suitable approach is the use of experience replay, a replay-based method in continual learning. Here, the system maintains a buffer of past flight experiences from North American operations and interleaves them during training on European data. This replay mechanism prevents the loss of critical older knowledge by reintroducing earlier data distributions alongside new ones. Alternatively, dual-model architectures such as Deep Generative Replay (DGR) (Shin et al., 2017) can simulate prior data using generative models, offering a memory-efficient way to maintain performance across domains.

Moreover, modular or architecture-based strategies, such as Progressive Neural Networks (PNNs) (Rusu et al., 2016), could be employed. In this case, the model learns a new set of parameters for European routing while maintaining frozen parameters for North American airspace. These modules are connected via lateral connections that allow for forward knowledge transfer without interfering with past learned features.

This scenario highlights a high-dimensional manifestation of the plasticity-stability trade-off. A system biased toward plasticity may be overfit to European routing peculiarities and fail to handle U.S.-based transcontinental routes. On the other hand, excessive stability may cause the model to ignore critical changes in the European operational environment, leading to suboptimal or non-compliant flight paths.

In sum, applying continual learning to global route optimization systems enables long-term deployment across diverse airspaces. By mimicking how human pilots and dispatchers accumulate operational experience over multiple regulatory domains, such systems can support safer and more efficient global aviation operations (Rusu et al., 2016; Parisi et al., 2019).

Discussion

The two case studies on predictive maintenance for multi-fleet engine diagnostics and adaptive flight routing across global airspaces serve to illustrate the profound significance of continual lifelong learning within the aviation industry. Their purpose is to concretely demonstrate how machine learning systems, inspired by human cognitive abilities, can address the inherent challenges of dynamic and safety-critical aviation environments. By presenting these examples, the discussion highlights both the practical benefits and complex struggles encountered when attempting to implement continual learning in real-world aviation systems.

At the heart of these case studies lies the principle that aviation AI must not only learn effectively from data but also accumulate knowledge over time, adapting to new information while retaining valuable prior experience. This mirrors the way human operators, be they maintenance technicians or flight planners, build upon their expertise incrementally, integrating lessons from past encounters even as they respond to novel situations. In predictive maintenance, for instance, the system must diagnose faults in both legacy engines and new models without losing diagnostic accuracy on either. Similarly, adaptive flight routing systems must navigate the intricacies of diverse regulatory frameworks and weather patterns, transferring knowledge seamlessly between geographically distinct airspaces.

The benefits of continual lifelong learning in aviation are manifold. Primarily, such learning enables enhanced adaptability, a critical requirement given the fast-evolving nature of aircraft technology, air traffic regulations, and operational contexts. Unlike traditional machine learning models, which are typically trained once and fixed, continual learning systems can update their understanding incrementally, reducing the need for complete retraining. This translates into significant operational cost savings and increased system longevity. Moreover, techniques like EWC and experience replay effectively mitigate the problem of catastrophic forgetting, which would otherwise cause AI models to lose proficiency in previously learned tasks as they absorb new data. Consequently, these systems better support operational efficiency and safety, allowing for more accurate fault predictions, optimized routing decisions, and compliance with ever-changing rules (Li & Hoiem, 2017).

However, implementing continual learning in aviation is not without its challenges. One of the fundamental hurdles is managing the delicate trade-off between plasticity and stability. On one hand, models must be sufficiently plastic to integrate new knowledge, such as unfamiliar engine behaviors or regional airspace regulations. On the other hand, they must maintain enough stability to preserve previously acquired expertise essential for safe operations. Striking this balance is difficult; excessive plasticity can lead to overwriting important information, resulting in performance degradation, while excessive stability can cause rigidity, preventing the system from adapting to new scenarios.

Beyond algorithmic concerns, continual learning also introduces complexities related to data management. To retain past knowledge, many approaches rely on storing historical data or generating synthetic examples, which can place significant demands on computational and storage resources. Furthermore, in a domain as tightly regulated and safety-critical as aviation, ensuring that adaptive systems can be thoroughly validated and certified is a major obstacle. Machine learning models that change over time challenge traditional verification processes, which assume fixed system behavior. However, the operational benefits of continual learning are significant. In predictive maintenance, continual learning allows earlier detection of emerging fault patterns, potentially reducing aircraft downtime and improving scheduling efficiency. For operators managing evolving fleets, continual learning reduces the need for repeated manual retraining of AI models, enabling seamless adaptation to new engine types or system upgrades. In global flight operations, continual learning supports safer and more flexible cross-border routing by allowing AI systems to adapt to diverse regulatory requirements and regional flight behaviors without sacrificing previously acquired knowledge. These capabilities mirror the adaptive expertise of human operators and offer practical value for maintaining safety and efficiency in a rapidly changing aviation landscape. As a result, regulatory frameworks must evolve to accommodate and oversee adaptive AI technologies.

Currently, the field is making promising strides. Foundational algorithms and architectural designs have been proposed and tested in controlled environments, suggesting the viability of continual learning for aviation tasks. Nonetheless, widespread deployment remains limited. Practical issues such as integration with existing avionics, computational constraints of onboard systems, and the scarcity of aviation-specific continual learning benchmarks slow progress (Olshausen & Field, 1996).

Looking ahead, the future of continual lifelong learning in aviation lies in hybrid approaches that combine multiple learning strategies to leverage their complementary advantages. Emphasis on model explainability and transparency will be critical to gaining operator trust and satisfying certification standards. Additionally, optimizing these learning algorithms for edge deployment, where decisions must be made rapidly on aircraft or unmanned vehicles, will be essential. A promising direction involves developing AI systems that work in partnership with human experts, enhancing situational awareness and decision-making through adaptive human-machine collaboration (Goodfellow et al., 2014).

Moreover, enhancing the robustness of continual learning models against unexpected distribution shifts, such as new failure modes, cyber threats, or sudden regulatory changes, will be crucial for maintaining operational reliability. Finally, advancing standardization and regulatory frameworks tailored to adaptive AI will pave the way for these systems to become integral components of aviation safety and efficiency in the coming decades.

In sum, the case studies underscore that continual lifelong learning is not merely a theoretical concept but a practical necessity for next-generation aviation AI. By enabling models to learn and adapt in a human-like manner, these approaches promise to transform aviation systems into resilient, intelligent agents capable of safely navigating the complexity and uncertainty of real-world operations.

Conclusion

This paper has explored the vital role of continual lifelong learning in advancing machine learning applications within the aviation industry. Through two detailed case studies, predictive maintenance across diverse engine fleets and adaptive flight routing in global airspaces, we demonstrated how continual learning enables AI systems to dynamically acquire new knowledge while retaining critical prior experience. This human-inspired learning paradigm addresses fundamental challenges posed by the ever-evolving nature of aviation operations, regulatory frameworks, and technological innovations.

The potential benefits of continual lifelong learning are clear: improved adaptability, enhanced safety, and greater operational efficiency. By mitigating catastrophic forgetting through methods such as EWC and experience replay, aviation AI can maintain reliability across changing conditions. However, balancing learning plasticity and memory stability remains a core challenge, compounded by the demands of data management, computational resources, and rigorous certification requirements.

Despite these challenges, recent algorithmic and architectural advances, coupled with growing interest from the aviation community, signal a promising future. Continued research focused on hybrid learning approaches, model interpretability, real-time edge deployment, and human-AI collaboration will be essential. Furthermore, evolving regulatory frameworks must embrace adaptive AI to fully unlock its potential.

An exciting avenue for future research lies in the integration of virtual laboratory environments to support continual learning frameworks in aviation. Virtual labs offer a controlled, scalable, and highly customizable platform for simulating diverse operational scenarios, sensor inputs, and fault conditions that may be rare or difficult to capture in real life. By leveraging these environments, continual learning models can be trained and validated across a broad spectrum of tasks and evolving conditions without risking actual system safety.

Ultimately, continual lifelong learning offers a pathway toward intelligent aviation systems that learn, adapt, and improve in ways akin to human operators. Such systems hold the promise to significantly elevate safety, efficiency, and resilience across the aviation ecosystem as it navigates the complexities of the 21st century.

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Appendix A. EWC Training Procedure for Continual Learning in Predictive Maintenance

The following pseudocode outlines the implementation of Elastic Weight Consolidation (EWC) to enable continual learning in a neural network model applied to multi-fleet engine diagnostics. The method mitigates catastrophic forgetting by selectively preserving important parameters from the original task (e.g., CFM56 engine fault prediction) during training on a new task (e.g., LEAP-1A engine diagnostics).

```
# Inputs:
# D_old: Dataset from old engine type (CFM56)
# D_new: Dataset from new engine type (LEAP-1A)
# Model: Predictive maintenance neural network
# λ: Regularization strength
# epochs: Number of training epochs

# Phase 1: Train on the old task
θ_star = Model.initialize_weights()
Model.train(D_old)
θ_star = Model.get_weights()  # Save trained weights

# Phase 2: Estimate Fisher Information Matrix (FIM)
F = {}
Model.eval()
for x, y in D_old:
    Model.zero_grad()
    loss = compute_loss(Model(x), y)
    loss.backward()
    for param in Model.parameters():
        if param.grad is not None:
            F[param] += (param.grad ** 2) / len(D_old)

# Phase 3: Train on the new task with EWC regularization
for epoch in range(epochs):
    for x, y in D_new:
        Model.zero_grad()

        # New task loss
        prediction = Model(x)
        L_new = compute_loss(prediction, y)

        # EWC regularization loss
        L_ewc = 0
        for param in Model.parameters():
            θ_i = param
            θ_i_star = θ_star[param]
            F_i = F[param]
            L_ewc += (F_i * (θ_i - θ_i_star).pow(2)).sum()

        # Combined loss
        L_total = L_new + (λ / 2) * L_ewc

        # Update parameters
        L_total.backward()
        optimizer.step()
```

Notes:

This pseudocode is adaptable to frameworks such as PyTorch or TensorFlow.

The F[param] entries approximate the diagonal of the Fisher Information Matrix, treating each model parameter independently.

The loss term

$$\mathcal{L}_{EWC} = \mathcal{L}_{new}(\theta) + \frac{\lambda}{2}\sum_{i} F_i(\theta_i - \theta_i^*)^2$$

is central to preserving knowledge while supporting adaptation.

This code is illustrative and may require modification depending on the specific architecture and task formulation. It provides a foundational strategy for deploying continual learning in real-world aviation diagnostics.

Appendix B. Computational Framework for Continual Learning in Adaptive Flight Routing

This appendix provides a conceptual outline and pseudocode for implementing a continual learning system for adaptive flight routing across diverse airspaces, as described in Case Study 2. The system must retain routing knowledge from a previously trained airspace domain (e.g., North America) while adapting to new regional rules and conditions (e.g., Eurocontrol airspace).

B.1 Model Architecture and Inputs

The routing model may be implemented as a reinforcement learning (RL) agent, a supervised deep neural network, or a hybrid policy-based system. The model takes the following inputs:

- **Aircraft state**: current location, heading, speed, altitude
- **Environmental features**: weather patterns, jet stream data, turbulence zones
- **Airspace regulations**: regional altitude rules, NOTAMs, restricted zones
- **Traffic density or slot availability**
- **Flight intent**: origin, destination, route constraints

The output is a sequence of waypoints or control decisions that optimize for criteria such as fuel efficiency, time, or safety under evolving constraints.

B.2 Continual Learning Integration

To ensure adaptability without forgetting previously learned airspace behavior, continual learning mechanisms are introduced:

- **Replay-based methods**: The model maintains a buffer of experiences (flight episodes) from previous environments. These are replayed alongside new data to prevent forgetting.
- **Regularization-based methods**: Elastic Weight Consolidation (EWC) or similar approaches constrain updates to critical model parameters identified from prior training.
- **Modular approaches**: Progressive Neural Networks (PNNs) create task-specific modules for each airspace, preserving old knowledge while enabling new learning through lateral connections.

B.3 Pseudocode for Replay-Based Continual Learning

The following pseudocode outlines a simplified training loop using experience replay to retain performance on prior airspace domains:

```
CopyEdit
# Initialize model and memory
model = initialize_model()
replay_buffer = initialize_replay_buffer()

# Load past experiences from North American operations
replay_buffer.load_old_domain_data("NorthAmerica")

# Training on new domain: Eurocontrol
for episode in training_episodes_Europe:
    state = environment.reset()
    done = False

    while not done:
        action = model.select_action(state)
        next_state, reward, done = environment.step(action)

        # Store new experience
        replay_buffer.add(state, action, reward, next_state)

        # Sample batch containing both old and new data
        batch = replay_buffer.sample_mixed_batch()

        # Compute and apply loss
```

```
        loss = compute_loss(batch)
        model.optimize(loss)

        state = next_state
```

This architecture ensures that while the model adapts to new routing behaviors, such as altitude transition rules or regional separation standards, it maintains proficiency in older environments, such as North Atlantic track systems or FAA-based separation logic.

B.4 Practical Considerations

- **Data simulation tools** such as BlueSky or OpenSky APIs can be used to generate realistic traffic and weather inputs for training.
- **Evaluation** should include transfer tests, where the model is assessed on previously learned environments after learning the new one, to quantify retention.
- **Modularity** is recommended when regulatory shifts are stark, to isolate and manage region-specific knowledge.

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A Pilot's Guide to the Engine-Out Glide: The Effect of Wind on Best Glide Speed

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In an effort to continue equipping pilots with the most accurate, clear, and useful information pertaining to engine-out glide performance, the author expanded the research to include the effects of wind on an airplane's v_G. The recommendations currently available for how to adjust v_G for winds will be discussed. The aerodynamic foundation of engine-out glide performance is presented to include the derivation of an analytical solution to the equation for v_G. The derivation is expanded, yielding an equation for v_G that accounts for headwinds and tailwinds. Numerical solutions to the equation and a graphical representation of the results are presented. Using the results, the author presents a method to quickly, easily, and accurately determine the effect of wind on v_G for any airplane. Suggestions are made for how pilots can use this information.

Recommended Citation:
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Introduction

Best range glide speed (a.k.a. best glide, v_G), published in Pilot's Operating Handbooks (POH), is the indicated airspeed (IAS) that allows an airplane, in a specified configuration (usually with landing gear retracted, flaps up, and the propeller control in the most advantageous position), to glide as far as possible from a given altitude after the total loss of engine power. The published speed is associated with the airplane at its maximum certified gross weight (MCGW), in a wings-level glide, with zero wind. Varying from the first two conditions was addressed by Callender (2023). This paper addresses the third: the effect of wind on best glide speed. For the purpose of clarity, the published (zero-wind) best glide speed will be symbolized by v_{G_0}; whereas, the symbol for best glide speed with wind will be v_{G_w}.

Information on the effects of wind on best glide speed can be found in popular (non-academic) sources. Cahill (2019), in an AOPA article, suggested adding half of the headwind component to v_{G_0} to obtain v_{G_w}. Lanning (2019), for the online aviation news service AVweb, suggested the same, with the addition of subtracting one-third of a tailwind from v_{G_0}. In an Aviation Safety article, Wolper (n.d.) provided a non-airplane-specific background on how v_{G_0} is determined. He included that v_{G_w} is higher than v_{G_0} with headwinds and lower with tailwinds, but specific guidance for determining v_{G_w} was not provided. Jurgens (2022), from Sporty's Flight Training Central, suggested adding one-third of a headwind to v_{G_0} and subtracting one-fifth of a tailwind. SKYbrary (n.d.), an International Civil Aviation Authority (ICAO) and a Flight Safety partner organization, noted the effect of wind on glide range but did not mention an effect on best glide speed. The Federal Aviation Administration (FAA) Safety Team (n.d.) published guidance to add half of a headwind to v_{G_0} and to subtract one-fifth of a tailwind. While these sources provide inconsistent guidance on determining v_{G_w}, they agree that v_{G_w} is higher with headwinds and lower with tailwinds.

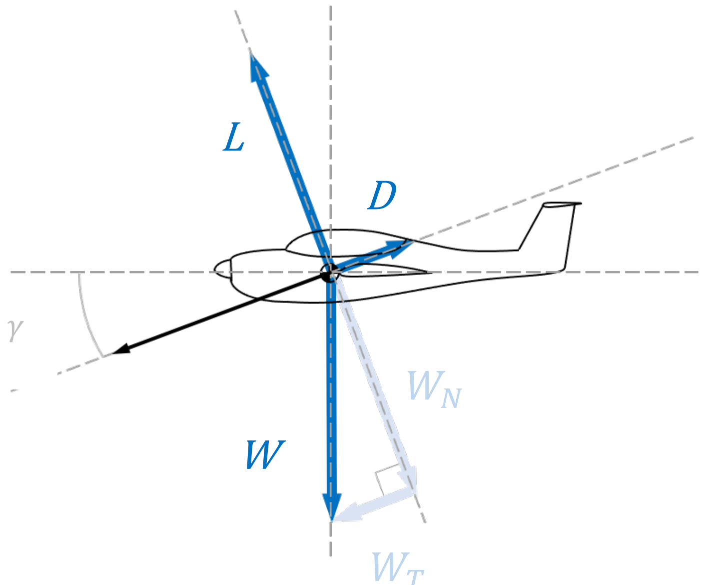
Peer-reviewed, academic articles have also addressed the effects of wind on best glide speed. Jenkins and Wasyl (1990) developed a numerical scheme with an associated graph of $v_{G_w}\ vs\ Wind$ for an example airplane (Schempp-Hirth Nimbus IIb). Bridges (1993) developed a fifth-order equation for v_{G_w} with a graph of both v_{G_w} and wind normalized by v_{G_0}. Segal, Bar-Gill, and Shimkin (2019) confirmed Bridges' solution and provided a graph of $v_{G_w}\ vs\ Wind$ for an example airplane (Cessna 172). The results in these articles for specific airplanes are practically applicable to those airplanes, but are not easily applied to other airplanes, nor are the general results for v_{G_w} palatable for pilots. This paper seeks to rectify both of these issues.

Best Range Glide Speed: Zero Wind

Identifying v_{G_0} Using Aerodynamic Forces

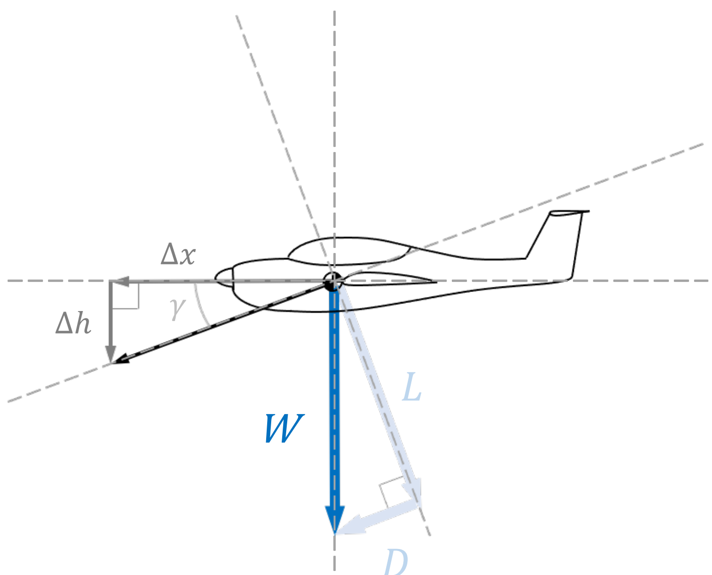
One method for identifying v_{G_0} is as follows. The forces acting on the airplane in an engine-out glide are shown in Figure 1. In the absence of thrust, a component of weight (W_T) in the direction of motion is required to counteract aerodynamic drag (D). In a steady glide, the components of weight are equal in magnitude to lift (L) and drag as shown in Figure 2.

Figure 1
Free Body Diagram of an Airplane in an Engine-Out Glide



Note. Adapted from Pilot's Guide to Maximum Glide Performance: Optimum Bank Angles in Gliding Turns (2023) by Callender, M.N.; retrieved from https://ojs.library.okstate.edu/osu/index.php/CARI/article/view/9516/8477.

Figure 2
Force Equivalencies and Distances in an Engine-Out Glide



Note. Adapted from Pilot's Guide to Maximum Glide Performance: Optimum Bank Angles in Gliding Turns (2023) by Callender, M.N.; retrieved from https://ojs.library.okstate.edu/osu/index.php/CARI/article/view/9516/8477.

Geometrically similar to the force triangle formed by weight, lift, and drag is the triangle formed by the airplane's direction of motion (the black vector), the distance it covers over the ground (Δx), and the altitude it loses (Δh) while gliding. The airplane's maximum glide range (R_G) will be achieved when its glide angle is minimized (γ_{min}). Descending at the minimum angle allows the airplane to cover the most distance over the ground for each unit of altitude lost. The ratio just described is known as the glide ratio (GR), as shown in Equation 1.

$$GR = \left(\frac{\Delta x}{\Delta h}\right)_{max} \tag{1}$$

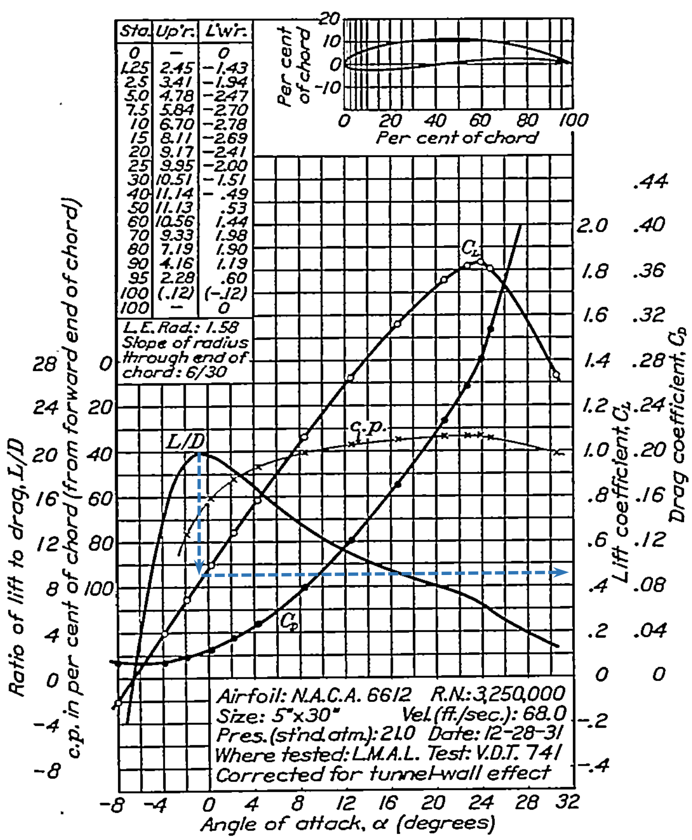
Since the force and distance triangles in Figure 2 are similar, the glide ratio can also be expressed in terms of forces as shown in Equation 2.

$$GR = \left(\frac{L}{D}\right)_{max} \tag{2}$$

This places glide performance on firm aerodynamic footing. $(L/D)_{max}$ is an important and well-known aerodynamic characteristic, found at the peak of a lifting shape's (i.e., an airfoil, a wing, or an airplane) L/D *vs angle of attack* (α) curve, an example of which is shown in Figure 3.

Figure 3

NACA 6612 Aerodynamic Characteristic Curves



Note. Adapted from The Characteristics of 78 Related Airfoil Sections from Tests in the Variable-Density Wind Tunnel, NACA-TR-460 (1933) by Jacobs, E., Ward, K.E., & Pinkerton, R.M., retrieved from ntrs.nasa.gov.

$(L/D)_{max}$ is achieved at a specific angle of attack. Using an airplane's lift coefficient $\left(C_{L_{opt}}\right)$ at this angle (e.g., following the blue arrows from $(L/D)_{max}$ in Figure 3) along with its MCGW as inputs into the lift equation, allows v_{G_0} to be calculated as shown in Equation 3.

$$v_{G_0} = \sqrt{\frac{2 \cdot MCGW}{C_{L_{opt}} \rho_0 S}} \tag{3}$$

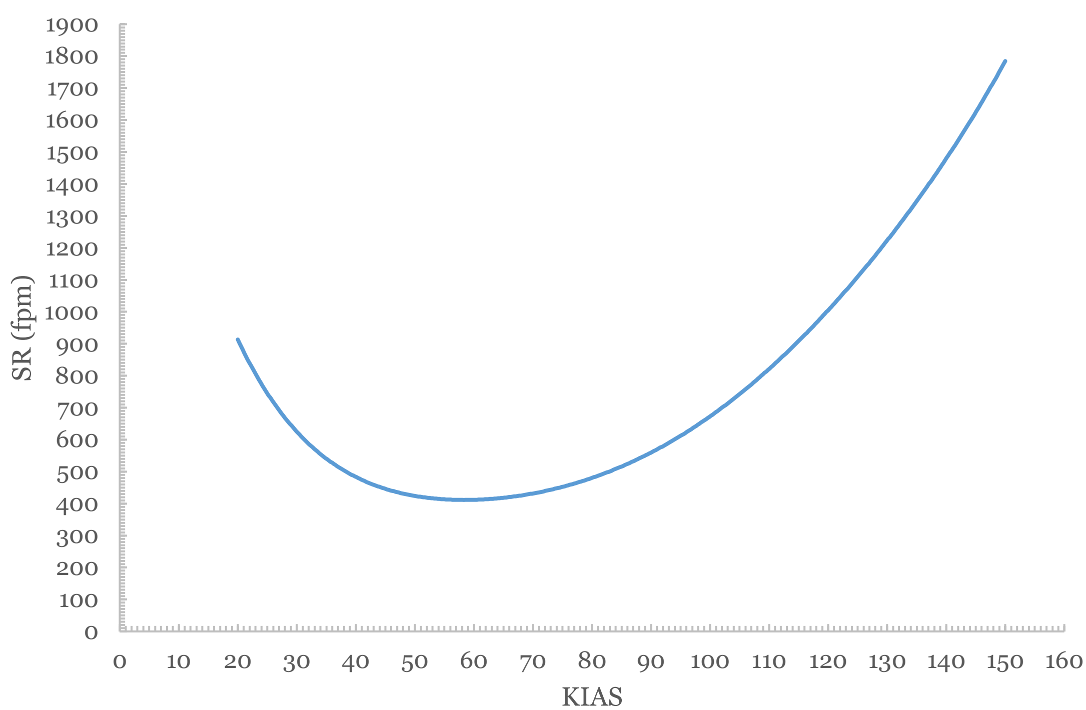
Identifying v_{G_0} Using Sink Rate Graphs

The method for determining v_{G_0} using aerodynamic forces as described in the previous section is technically correct; however, it is not the actual method used to find v_{G_0} nor is it the common way used to communicate v_{G_0} in academic and popular literature.

The sawtooth glide is a common flight test method used to obtain data necessary to identify v_{G_0}. The test is composed of a series of engine-out glides through an altitude band. The first glide is conducted at a constant airspeed, and the time to descend through the altitude band is recorded. Every subsequent glide is conducted at a different airspeed. The results of the test are the times that an airplane takes to descend through a fixed altitude band at various indicated airspeeds (IAS). By dividing the altitude band by the descent times (and appropriate unit conversions and corrections), the airplane's sink rates (SR) are calculated for various airspeeds. The results can be plotted as shown in Figure 4.

Figure 4

Example SR vs IAS Chart



The axes of a sink rate plot can be thought of in more basic mathematical terms. Sink rate is the change in altitude for a given amount of time and can be symbolized by $\Delta h/\Delta t$. Indicated airspeed is closely approximated to the airplane's ground distance covered in a given amount of time and can be symbolized by $\Delta x/\Delta t$. Figure 5 shows a sink rate plot using these symbols to represent the vertical and horizontal components of one point on the sink rate curve. With a line drawn from the origin to the point, as shown in Figure 5, the vertical and horizontal components represent the opposite (opp) and the adjacent (adj) sides of a right triangle. The tangent of the angle (θ) is calculated by Equation 4.

$$tan\theta = \frac{opp}{adj} = \frac{\Delta h/\Delta t}{\Delta x/\Delta t} = \frac{\Delta h}{\Delta x} \tag{4}$$

The result $(\Delta h/\Delta x)$ represents the altitude lost in the glide divided by the ground distance covered. This is the inverse of the right side of Equation 1. Since Equation 1 presents the condition for maximum glide range, minimizing Equation 4 also represents maximum glide range. Minimizing $tan\theta$ is accomplished by minimizing θ. This process is visualized in Figure 6. Point 1 is the original point from Figure 5. Point 2 is an SR point at a slightly higher indicated airspeed. Notice that the angle of the line from the origin to Point 2 is smaller than the line to Point 1. The angles continue to decrease for subsequent points until reaching the point of tangency (Point 3) between the sink rate curve and a line from the origin. Points at higher indicated airspeeds (i.e., Point 4) have higher angles. Since the angle of the line to Point 3 is the minimum angle, the airspeed associated with it is v_{G_0}.

Figure 5
Basic Representations of SR Point Coordinates

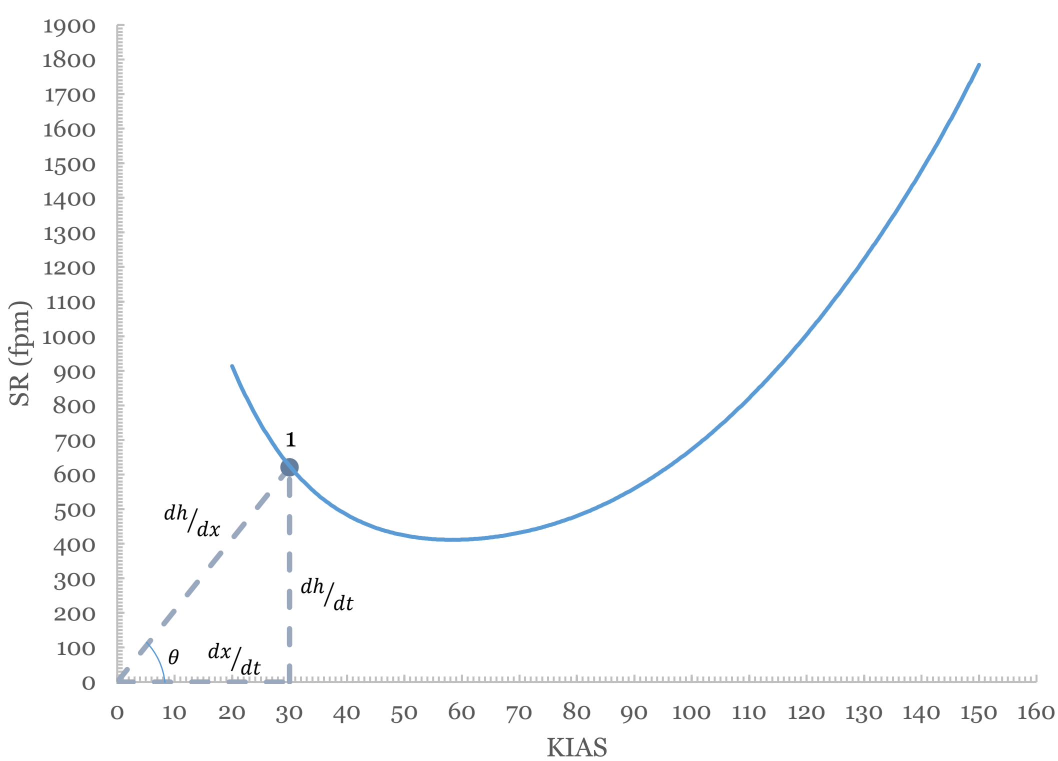
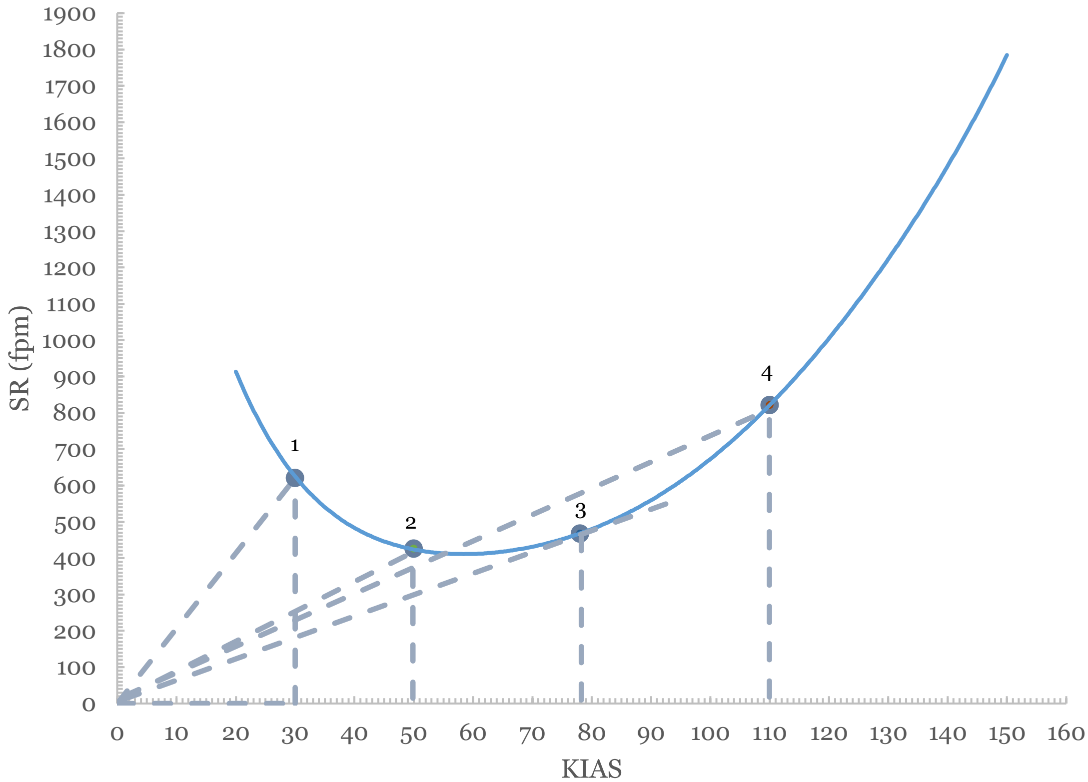


Figure 6
Identifying the SR Point with Minimal θ



v_{G_0} Analytic Solution

Basic aerodynamic principles will now be combined with the sink rate curve technique to find the analytic solution for v_{G_0}. The buildup will begin with the basic aerodynamic equation for lift coefficient that leads to the equation for drag as shown in Equations 5-8.

$$C_L = \frac{2W}{\rho v^2 S} \tag{5}$$

$$C_{D_i} = \frac{C_L^2}{\pi ARe} = \frac{4W^2}{\pi ARe\rho^2 v^4 S^2} \tag{6}$$

$$C_D = C_{D_0} + C_{D_i} \tag{7}$$

$$D = \frac{1}{2} C_D \rho v^2 S = \frac{C_{D_0} \rho v^2 S}{2} + \frac{2W^2}{\pi ARe\rho v^2 S} \tag{8}$$

The aerodynamic drag, from Equation 8, created by an airplane at a given airspeed, leads to the power required to glide at that airspeed. Power required, in the practical unit of horsepower, can be calculated using Equation 9.

$$HP_R = \frac{Dv}{550} = \frac{C_{D_0} \rho v^3 S}{(2)(550)} + \frac{2W^2}{(550)\pi ARe\rho v S} \tag{9}$$

HP_R from Equation 9, along with an airplane's weight (W), is used to calculate sink rate as a function of airspeed in Equation 10.

$$SR = \frac{33000 HP_R}{W} = \frac{(33000) C_{D_0} \rho v^3 S}{(2)(550) W} + \frac{(33000)(2) W}{(550)\pi ARe\rho v S} \tag{10}$$

This equation produces an airplane's sink rate curve like those depicted in Figures 4-6 from its basic drag characteristics (i.e. $C_{D_0}$and e), its wing's geometric characteristics (i.e. S and AR), and its weight. The equation for the tangent line from the origin to Point 3 on Figure 6 is given by Equation 11.

$$SR = mv \tag{11}$$

Since this line is on an *SR* vs *IAS* graph, its x-coordinate is airspeed (v) and its y-coordinate is sink rate. The slope is simply represented by m. At the point of tangency (Point 3 on Figure 6) between the sink rate curve (Equation 10) and the line from the origin (Equation 11), the slopes of the two are equal. The slopes of Equations 10 and 11 are found by taking their derivatives with respect to velocity as presented in Equations 12 and 13, respectively.

$$\frac{dSR}{dv} = \frac{(3)(33000)C_{D_0}\rho v^2 S}{(2)(550)W} - \frac{(33000)(2)W}{(550)\pi ARe\rho v^2 S} \tag{12}$$

$$\frac{dSR}{dv} = m \tag{13}$$

Setting these equal to one another yields Equation 14.

$$m = \frac{(3)(33000)C_{D_0}\rho v^2 S}{(2)(550)W} - \frac{(33000)(2)W}{(550)\pi ARe\rho v^2 S} \tag{14}$$

Equation 14 can then be substituted into Equation 11, resulting in a new equation for the tangent line as shown in Equation 15.

$$SR = \frac{(3)(33000)C_{D_0}\rho v^3 S}{(2)(550)W} - \frac{(33000)(2)W}{(550)\pi ARe\rho v S} \tag{15}$$

The outputs of Equation 15 for the tangent line and of Equation 10 for the sink rate curve are equal at the point of tangency. Equating the two yields Equation 16.

$$\frac{(3)(33000)C_{D_0}\rho v^3 S}{(2)(550)W} - \frac{(33000)(2)W}{(550)\pi ARe\rho v S} = \frac{(33000)C_{D_0}\rho v^3 S}{(2)(550)W} + \frac{(33000)(2)W}{(550)\pi ARe\rho v S} \tag{16}$$

Solving Equation 16 for v results in the indicated airspeed in mean sea level (MSL) conditions with zero wind that provides the most range in an engine-out glide. This solution, shown in Equation 17, is the analytic solution to v_{G_0}.

$$v_{G_0} = \sqrt[4]{\frac{4W^2}{C_{D_0}\pi ARe\rho^2 S^2}} \tag{17}$$

Equation 17 allows v_{G_0} to be calculated from an airplane's basic aerodynamic and geometric characteristics.

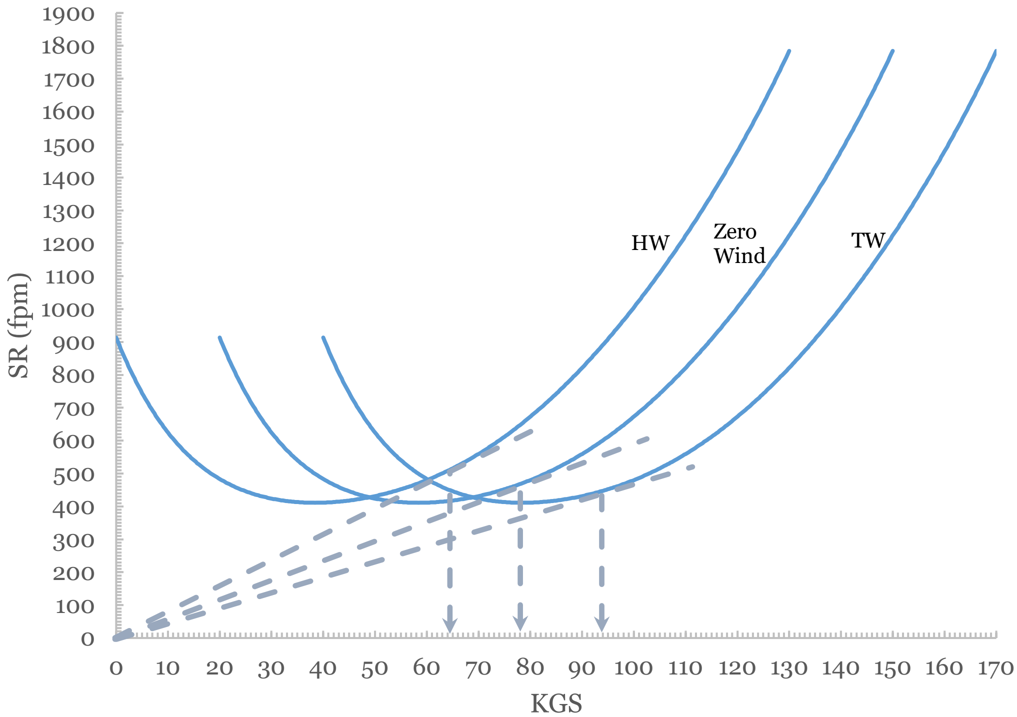
Best Range Glide Speed: With Wind

Identifying v_{G_w} Using Graphical Methods

The sink rate curve technique for finding v_{G_0} will now be applied to finding the best range glide speed with wind, v_{G_w}. Figure 6 shows that v_{G_0} was associated with the point of tangency between an airplane's sink rate curve and a line from the origin. In sea level conditions with no wind, the indicated airspeed axis is the same as ground speed. With wind, this is not the case, and since maximizing glide distance over the ground is important, finding v_{G_w} must deal with ground speed in one of two ways. The first graphical method is to draw a tangent line to an airplane's sink rate curve, not from the origin, but from the headwind or the tailwind value on the airspeed axis. The graphic representation showing the effects of headwinds and tailwinds using this method is found in current literature and was also the basis for Bridges' (1993) analytic solution. The other method is presented in this paper. It begins not by shifting the location from which the tangent line is drawn (it will begin at the origin) but by shifting the airplane's sink rate curve left or right by the amount of headwind or tailwind, respectively. This method transforms the horizontal axis from an indicated airspeed axis to a groundspeed axis. This means that the airspeed associated with the point of tangency is the groundspeed that gives the most range in the glide. Adding the headwind or tailwind magnitude to this value yields v_{G_w}. Figure 7 shows examples of shifted sink rate curves for finding v_{G_w} with headwinds and tailwinds.

Figure 7

Identifying v_{G_w} with Headwinds and Tailwinds



Note: The speeds identified by the arrows represent the ground speeds for best range for each wind condition. The wind speed must be added (HW) or subtracted (TW) in order to yield v_{G_w}).

v_{G_w} Equation Derivation

The graphical process of finding v_{G_w} by shifting the sink rate curve to the left or right for headwinds or tailwinds, respectively, can be applied to finding an analytic solution. Equation 10, representing an airplane's sink rate curve, can be shifted for wind (w) as shown in Equation 18.

$$SR = \frac{(33000)C_{D_0}\rho(v+w)^3 S}{(2)(550)W} + \frac{(33000)(2)W}{(550)\pi ARe\rho(v+w)S} \qquad (18)$$

In this equation, headwinds are positive and tailwinds are negative. The same process described above, using Equations 10-16, can be followed by substituting Equation 18 for Equation 10. This process results in Equation 19.

$$(v+w)^5 - 3(v+w)^4 v + \frac{4W^2}{C_{D_0}\pi ARe\rho^2 S^2}(v+w) + \frac{4W^2}{C_{D_0}\pi ARe\rho^2 S^2}v = 0 \qquad (19)$$

Equation 19 can then be simplified with the substitution of Equation 17, from the no-wind case, resulting in Equation 20.

$$(v+w)^5 - 3(v+w)^4 + v_{G_0}^4(v+w) + v_{G_0}^4 v = 0 \tag{20}$$

One of the solutions (roots) to this fifth-order polynomial, for a given wind speed, will be the groundspeed that gives the best glide range, to which the wind speed can be added to find v_{G_w}. The alternate method for visualizing v_{G_w} or for analytically deriving an equation for v_{G_w} is to have the line tangent to the sink rate curve in Figure 6 originate from the wind speed on the horizontal axis. The advantage of this method is that the speed associated with the tangent point is v_{G_w}. There is no need to add wind speed to ground speed. This method was used by Bridges (1993). Whether using Bridges' equation or Equation 20, a mathematical hurdle must be overcome. According to the Abel-Ruffini theorem, fifth-order polynomials (i.e., Equation 20) have no known analytical solution. Fortunately, they can be solved numerically (Abel, 1824). An online numerical solver was used to find the roots of Equation 20 (Wolfram Alpha, 2025). For specific v_{G_0} and w values, the appropriate root corresponding to the tangent point between the wind-shifted sink rate curve and a line drawn from the origin (with a positive slope) is the ground speed resulting in the best glide range. Adding the wind speed results in v_{G_w}.

Verification of Methods

The graphical and analytical methods for finding v_{G_0} and v_{G_w} will first be demonstrated using an example airplane. Table 1 includes the example airplane's necessary characteristics.

Table 1
Example Airplane Characteristics

W (lbs)	S (ft^2)	AR	C_{D_0}	e
2535	145.5	10.7	0.025	0.85

Applying these characteristics to Equation 17 yields the airplane's v_{G_0} as shown in Equation 21.

$$v_{G_0} = \sqrt[4]{\frac{4(2535)^2}{(0.025)\pi(10.7)(0.85)(0.00238)^2(145.5)^2}} = 131.6\ fps\ or\ 78.0\ KIAS \tag{21}$$

The characteristics from Table 1 were used to create the sink rate curve in Figure 6. Using the graphical method, the airspeed corresponding to Point 3 on Figure 6 is also 78.0 $KIAS$. Using Wolfram Alpha to find numerical solutions to Equation 20 for this example airplane for 20 $knot$ headwinds and tailwinds yield v_{G_w} values of 84.4 $KIAS$ for 20 $knot$ headwinds and 73.9 $KIAS$ for 20 $knot$ tailwinds. The graphical method depicted in Figure 7 for this airplane shows ground speeds associated with the best glide range for 20 $knot$ headwinds and tailwinds that match these values after adding and subtracting headwinds and tailwinds to convert ground speeds to airspeeds. The graphical and the analytical methods for determining v_{G_0} and v_{G_w} agree with one another.

Application

While understanding 1) the process presented in Figure 5 for finding v_{G_0} provides pilots with insight, and 2) Equation 17 allows a pilot to calculate v_{G_0} if an airplane's characteristics are available, neither of these is actually necessary. Pilots need only to consult an airplane's pilot's operating handbook (POH) or its airplane flight manual (AFM) to find v_{G_0}. What POHs don't typically include are the adjustments to v_{G_0} for airplane weights less than the maximum certified gross weight (see Callender (2023)) or the adjustments for wind. Table 2 contains v_{G_w} values for a range of wind speeds for different values of v_{G_0} obtained from solutions to Equation 20. These values can be plotted as shown in Figure 8. Each curve in Figure 8 shows the range of v_{G_w} for a given v_{G_0}(the value at the y-intercept). A pilot can first find the curve associated with an airplane's v_{G_0}. Next, the pilot can read vertically from the wind speed to the airplane's v_{G_0} curve. Reading horizontally from this point to the vertical axis yields the airplane's v_{G_w} for the selected wind speed. An example of this process is shown in Figure 8 for an airplane with $v_{G_0} = 70\ KIAS$ and a headwind of $20\ knots$. The pilot quickly and easily sees that the airplane's $v_{G_w} \approx 77\ KIAS$. Plotting the results of Equation 20 in the form of Figure 8 can be accomplished for every possible value of v_{G_0} and can include the effects of any wind speed. An example including curves, inclusive of the range of v_{G_0} seen in most general aviation airplanes, is seen in Figure 9.

Table 2

Best Range Glide Speeds with Headwinds and Tailwinds

$v_{G_w}(KIAS)$				v_{G_0}	$v_{G_w}(KIAS)$			
Headwinds (*knots*)					Tailwinds (*knots*)			
40	30	20	10		-10	-20	-30	-40
79.4	72.2	66.9	62.9	60	57.8	56.2	54.9	53.8
87.6	81.4	76.5	72.8	70	67.8	66.0	64.6	63.5
96.3	90.7	86.3	82.8	80	77.8	75.9	74.4	73.2
105.4	100.3	96.1	92.8	90	87.7	85.8	84.3	82.9
114.7	110.0	106.0	102.7	100	97.7	95.1	94.1	92.7

Figure 8
Best Range Glide Speeds with Headwinds and Tailwinds

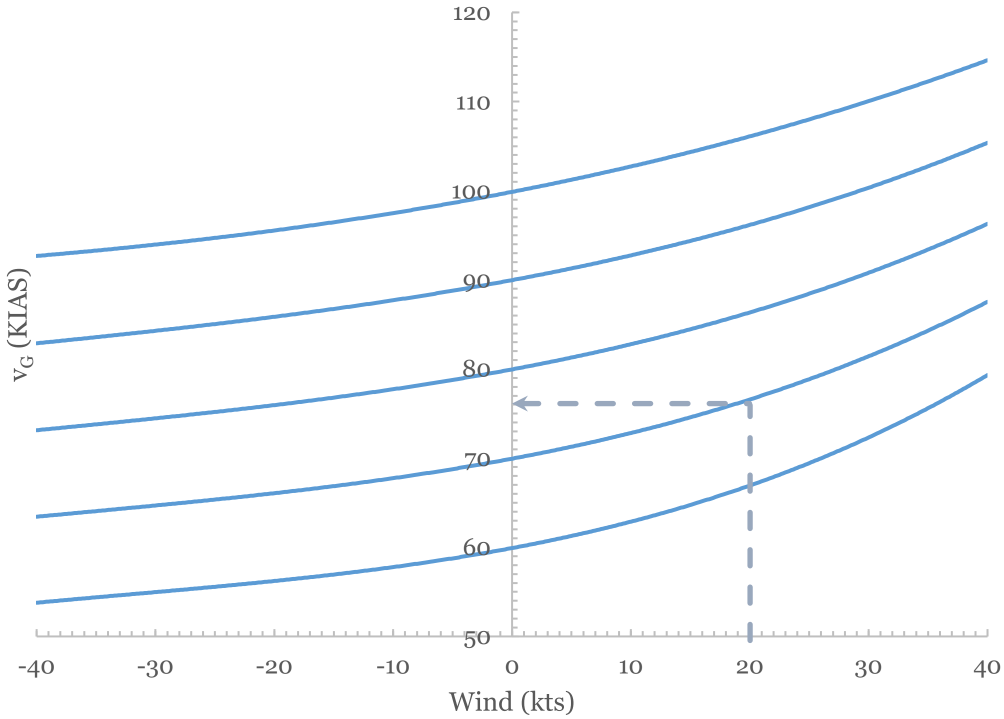
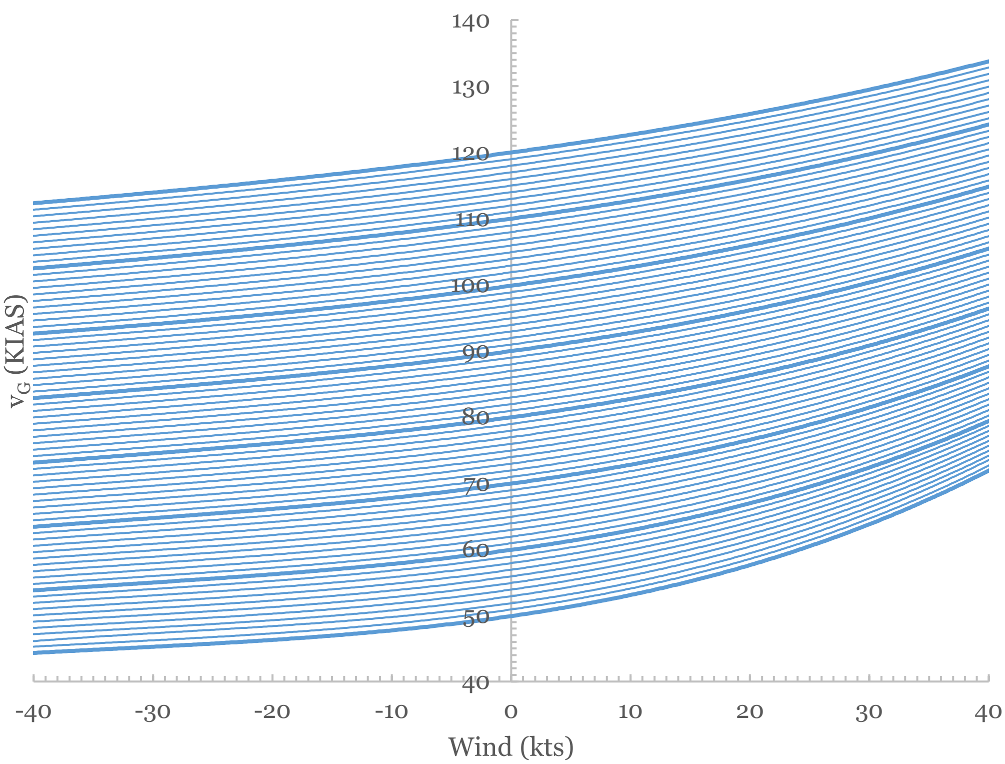


Figure 9
Best Range Glide Speed Curves for General Aviation Airplanes



Recommendations

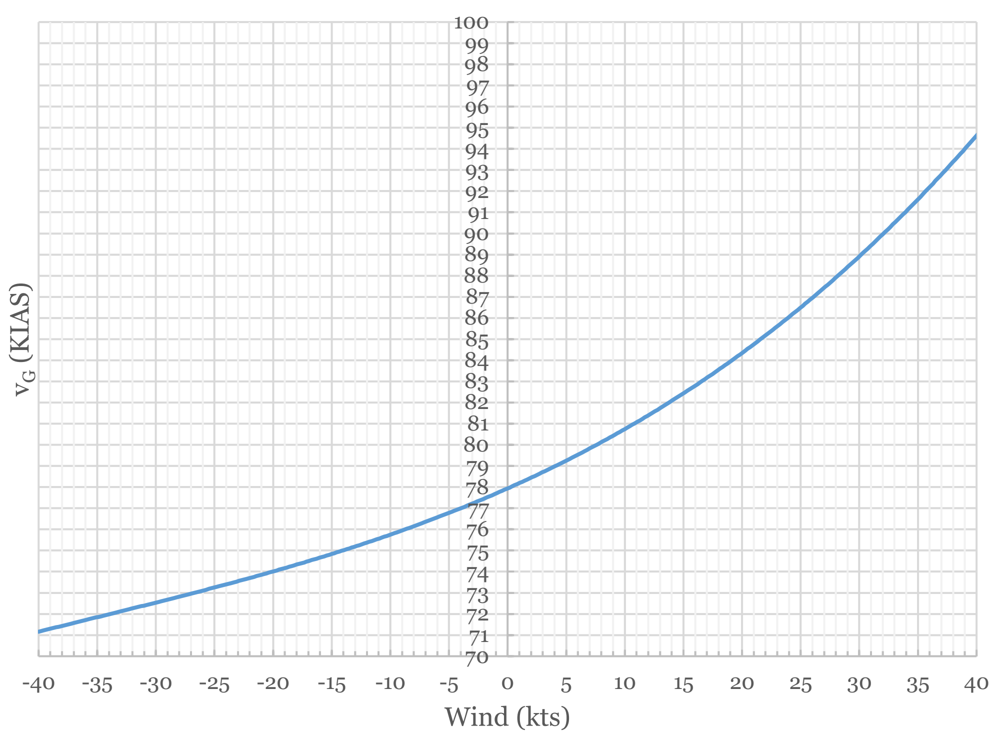
Regarding the information presented in this paper for determining any airplane's best range glide speed in any wind condition, the author makes the following recommendations.

The first recommendation is that pilot training and reference materials should adequately cover the effect of wind on an airplane's best range glide speed. As presented in the introduction, limited information on this subject is available. The information that is available is not found in commonly used pilot training/informational publications such as the FAA's Airplane Flying Handbook (AFH) or the Pilot's Handbook of Aeronautical Knowledge (PHAC), the classic Aerodynamics for Naval Aviators, nor is it found in POHs or AFMs. Non-airplane specific publications (i.e., the AFH or the PHAC) should include an explanation of the effects of wind supported by a visual similar to Figure 7, followed by either Figure 8 or Figure 9 showing v_{G_w} curves applicable to most general aviation airplanes. Airplane specific POHs or AFMs can/should do better. For the example airplane used earlier in this paper with $v_{G_0} = 78\ KIAS$, its POH could include either a table of its v_{G_w} values for various headwind and tailwind values, or it could include a visual representation of v_{G_w} as presented in Figure 10.

The next recommendation is that flight training should include the practice of determining and holding v_{G_w} in simulated engine-out glides based upon actual wind magnitude and glide direction.

Figure 10

POH Graph of v_{G_w} for an Airplane with $v_{G_0} = 78\ KIAS$



The final and potentially the most impactful recommendation is that the airplane-specific information for v_{G_w} (the equation for the specific curve from Figure 9) should be programmed into digital avionics and flight management systems. These systems can then calculate and display to the pilot the real-time v_{G_w} based upon either the reported or the calculated wind speed.

Readers who desire a graph of v_{G_w} for their airplane, similar to Figure 10, can either isolate the appropriate curve from Figure 9 and create their own airplane-specific graph or are welcome to contact the author.

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Land Use Guidelines for Drone Hubs in the U.S.: Optimal Site Selection and Policy Frameworks

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This study investigated public preferences regarding drone hub siting through a quantitative survey of 1,023 U.S. respondents. The findings reveal an overwhelming consensus (97.9%) in support of banning drone hubs near sensitive areas, such as residential neighborhoods and schools. Residential settings significantly influenced distance preferences, with urban residents showing greater acceptance of closer proximities (52.0% preferred 1/2 mile to 1 mile) compared to rural residents who favored greater distances (51.7% preferred 1 mile to 2 miles). Chi-square tests confirmed statistically significant relationships ($p < .001$) between residential settings, distance preferences, and noise tolerance. Gender and age also significantly influenced drone acceptance levels, with females and younger respondents showing more positive attitudes. The most effective mitigation measures included noise reduction technology (63.0%), limited operating hours (61.2%), and community involvement (56.0%). Based on these findings, the study proposes evidence-based guidelines for drone hub siting that include tiered setback requirements, context-sensitive noise standards, operational restrictions, and comprehensive stakeholder engagement strategies. These quantitative parameters provide a foundation for sustainable drone infrastructure development that balances technological advancement with community acceptance.

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Introduction

The rapid advancement of drone technology has transformed various industries, offering unprecedented capabilities in logistics, surveillance, infrastructure inspection, and emergency services. As the Federal Aviation Administration (FAA) continues to refine regulations governing unmanned aircraft systems (UAS), the emergence of drone hubs—dedicated facilities supporting drone operations, maintenance, and logistics—has become a significant development in transportation infrastructure planning (FAA, 2023a). These hubs serve as critical nodes for commercial drone operations, supporting activities that range from package delivery to the transportation of medical supplies.

The drone industry has experienced exponential growth, with the FAA reporting over 867,000 registered drones in the United States as of 2023 (FAA, 2023b). This proliferation has been driven by technological innovations, decreasing costs, and expanding commercial applications. Companies, including Amazon, UPS, and Wingcopter, have pioneered drone delivery services, while government agencies increasingly deploy drones for public safety, infrastructure inspection, and emergency response operations (Merkert & Bushell, 2020). The emergence of urban air mobility concepts has further accelerated interest in drone infrastructure, with projections suggesting that the commercial drone market could reach $11.2 billion by 2026 (Goldman Sachs, 2020).

Problem Statement

Despite their potential benefits, integrating drone hubs into existing urban and suburban landscapes presents significant challenges. Unlike traditional transportation infrastructure, drone operations occur in three-dimensional space, creating novel concerns regarding airspace management, safety, noise pollution, and privacy (Dukowitz, 2022). Local governments often lack the necessary regulatory frameworks and technical expertise to evaluate and approve drone hub proposals, resulting in inconsistent and sometimes inadequate land-use decisions. The Federal Aviation Administration's authority primarily covers airspace regulation, leaving a regulatory gap in land use planning that local jurisdictions must address (Clothier et al., 2015).

Furthermore, community opposition to drone operations has emerged as a substantial barrier to implementation. Concerns about noise, visual disturbance, privacy infringement, and safety risks have fueled resistance to drone hub development in residential and mixed-use areas (Rothstein, 2022). Without clear guidelines for site selection and operation based on public preferences and concerns, these conflicts threaten to impede the advancement of beneficial drone technologies. Research has shown that public acceptance is crucial for the successful deployment of new transportation technologies, and negative community reactions can significantly delay or prevent infrastructure projects (Gkartzonikas & Gkritza, 2019).

Research Questions

The study was guided by the following research questions:

1. What are public preferences regarding acceptable distances between drone hubs and sensitive areas?

2. How do demographic factors such as age, gender, and residential setting influence drone acceptance levels?

3. What mitigation measures are perceived as most effective in increasing acceptance of drone hubs?

4. How do noise perception and tolerance vary among different community types?

Objectives

This research aims to develop comprehensive land use guidelines for drone hub site selection and operation in the United States, based on quantitative survey data of public preferences and concerns. Specifically, the study seeks to identify optimal site selection criteria that balance operational requirements with community impact considerations, quantify public perceptions regarding acceptable distances between drone hubs and various land uses, evaluate the effectiveness of different mitigation strategies in increasing public acceptance of drone operations, and develop evidence-based policy recommendations for integrating drone hubs into urban and suburban environments.

By providing a robust analytical foundation for drone hub planning based on public input, this research intends to facilitate the responsible development of drone infrastructure while mitigating potential negative impacts on communities. The study addresses a critical gap in the literature by providing quantitative data on public preferences that can inform evidence-based policy development rather than relying solely on theoretical frameworks or expert opinions.

Literature Review

This section organizes a review of literature related to federal regulations, public acceptance, land use approaches, noise impacts, and technological considerations associated with drone operations.

Federal Regulations and Governance

The regulatory framework for drone operations in the United States is primarily established by the Federal Aviation Administration (FAA). Since introducing Part 107 regulations in 2016, which set the foundational rules for commercial drone operations, the FAA has continued to refine its approach to integrating unmanned aircraft systems (UAS) into national airspace (FAA, 2021). These regulations established operational limitations, including maintaining a visual line of sight (VLOS), flying below 400 feet, and avoiding operations over people without specific waivers or certifications.

The Remote ID requirements, which came into full effect in March 2024, represent a significant advancement in drone regulation. As the FAA (2024) described, Remote ID functions as a "digital license plate" that broadcasts information about the drone and its location during operation. This system enhances safety and security by enabling authorities to identify drones operating within their jurisdiction. The implementation of Remote ID has been viewed as a critical enabler for more advanced operations, including beyond visual line-of-sight flights and operations over people (Rao et al., 2016).

However, while these federal regulations provide a foundation for drone operations, they primarily focus on airspace management and safety, rather than land use considerations for drone infrastructure. This regulatory gap has created challenges for local governments in establishing appropriate zoning and permitting requirements for drone hubs. The intersection of federal airspace authority and local land use control remains a complex area that requires coordination between multiple levels of government (Pauner et al., 2018).

Community Concerns and Public Acceptance

Research on public acceptance of drone technology has identified several key concerns influencing community responses to drone operations. Noise has consistently emerged as one of the primary concerns, with studies indicating that drone noise is often perceived as more annoying than other transportation sounds at equivalent decibel levels (Christian & Cabell, 2017; Ison, 2023; Torija et al., 2019). The unique acoustic characteristics of drone noise, particularly its tonal qualities and intermittent nature, contribute to higher annoyance ratings compared to continuous noise sources, such as highway traffic (Schäffer et al., 2021).

Visual impact represents another significant concern, particularly in residential areas. Yoo et al. (2018) found that the visibility of drones reduced the perceived quality of life in residential neighborhoods, with operational frequency being a key factor influencing acceptance levels. The psychological impact of seeing drones overhead has been linked to concerns about surveillance and privacy, even when drones are not equipped with cameras or are being used for surveillance purposes (Clothier et al., 2015). Privacy concerns have also been identified as a significant barrier to public acceptance, with surveys indicating widespread anxiety about the surveillance capabilities of drones operating over residential areas (Wang et al., 2021).

Additionally, safety perceptions significantly influence public attitudes toward drone operations. Rice et al. (2018) found that concerns about mechanical failures, operator errors, and potential crashes were prevalent among survey respondents, particularly those unfamiliar with drone technology. These safety concerns are often exacerbated by media coverage of drone incidents and near-misses with aircraft despite statistical evidence showing relatively low actual risk levels (Rao et al., 2016). The perceived risk often exceeds the actual risk, highlighting the importance of public education and transparent communication about safety measures.

Land Use Planning Approaches and Integration Strategies

Several studies have explored approaches to integrating drone infrastructure into urban and regional planning frameworks. Bauranov et al. (2021) proposed a multi-criteria decision-making approach to selecting drone hub sites, incorporating population density, existing transportation networks, noise sensitivity, and operational requirements. Their model emphasized the importance of buffer zones between drone operations and sensitive land uses, suggesting that spatial separation is crucial in maintaining community acceptance.

Freeman and Freeland (2022) analyzed zoning approaches for drone infrastructure in five U.S. cities, identifying emerging practices such as designated drone corridors, overlay districts, and performance-based standards. Their research highlighted the value of adapting existing land use tools to address the unique characteristics of drone operations, rather than creating entirely new regulatory frameworks. The study found that cities taking proactive approaches to drone regulation were better positioned to accommodate drone infrastructure while protecting community interests.

The concept of designated drone corridors has gained particular attention as a planning tool for managing urban drone operations. These corridors, typically aligned with existing transportation infrastructure such as highways and railways, provide predictable flight paths that minimize impacts on residential areas while maintaining operational efficiency (Kopardekar et al., 2016). Research by Pongsakornsathien et al. (2020) demonstrated that well-designed corridor systems could reduce noise exposure to residential areas by up to 40% compared to unrestricted flight patterns.

Community engagement has been identified as a critical factor in the successful implementation of drones, complementing these planning approaches. Kuzma et al. (2021) documented significant improvements in public acceptance following transparent engagement processes that addressed concerns, demonstrated the technology, and incorporated community feedback into operational guidelines. Their research emphasized that engagement must begin early in the planning process and continue throughout implementation to maintain community support. Similarly, Lidynia et al. (2017) found that public participation in drone policy development resulted in more nuanced and effective regulations that strike a balance between innovation and community protection.

Noise Impact and Mitigation Research

Extensive research has been conducted on the characteristics of drone noise and its impact on communities. Schäffer et al. (2021) conducted field studies measuring community response to drone noise, finding that the intermittent and unpredictable nature of drone operations contributes to higher annoyance levels compared to steady-state noise sources. Their research suggested that noise metrics developed for traditional aircraft may not accurately predict community responses to drone operations, necessitating the development of drone-specific assessment methods.

Technological approaches to noise reduction have shown promise in addressing community concerns. Research by Intaratep et al. (2016) demonstrated that modifications to propeller design and shrouding could reduce drone noise by 10-15 decibels without significantly impacting performance. Similarly, studies of electric propulsion systems have shown potential for quieter operations compared to internal combustion engines, though battery limitations continue to constrain operational range and payload capacity (Bacchini & Cestino, 2019).

The temporal aspects of noise exposure have also been the focus of recent research. Torija et al. (2020) found that community acceptance of drone noise was significantly influenced by time of day, with evening and night operations generating substantially higher complaint rates even at lower sound levels. This research suggests that operational restrictions based on time of day may be more effective than absolute noise limits in maintaining community acceptance.

Technological and Economic Considerations

Rapid technological development in the drone industry has important implications for land use planning. Advances in battery technology, autonomous navigation, and collision avoidance systems are expanding the operational capabilities of drones while potentially reducing some community concerns (Kopardekar et al., 2016). However, these technological improvements also enable more intensive operations, potentially increasing the impact on communities if not adequately managed through planning and regulation.

Economic considerations play an increasingly important role in drone hub planning decisions. Research by McKinsey & Company (2020) estimated that drone delivery services could generate $100 billion in annual economic value by 2030, provided that regulatory and community acceptance challenges are successfully addressed. The potential economic benefits of drone operations, including reduced delivery costs, decreased traffic congestion, and environmental benefits from reduced vehicle emissions, provide compelling arguments for communities to accommodate drone infrastructure.

The existing literature offers valuable insights into regulatory frameworks, community concerns, technological advancements, and planning strategies. However, a need remains for quantitative research on public preferences regarding specific siting criteria, acceptable distances, and mitigation measures to guide evidence-based planning decisions for drone hub development. This study addresses that gap by providing comprehensive survey data on public preferences that can inform policy development and planning decisions.

Methodology

This section describes the methodology and design used to conduct this study, including the process by which survey participants were engaged and selected, as well as information on whether incentives were provided. It also explains the rationale for using chi-square tests as the primary statistical method, given their suitability for analyzing categorical data where variables are independent of each other.

Research Design

This study employed a quantitative research approach, utilizing a cross-sectional survey design, to gather data on public perceptions, preferences, and concerns regarding the siting and operation of drone hubs. The survey was designed to capture specific metrics on acceptable distances, noise tolerance levels, visual impact concerns, and mitigation preferences, informing evidence-based drone hub land use planning guidelines. The research design was informed by previous studies on public acceptance of transportation infrastructure and adapted to address the unique characteristics of drone operations (Gkartzonikas & Gkritza, 2019).

Survey Instrument Development

The survey instrument consisted of 27 questions covering four key areas:
1. Respondents' familiarity with drones and general attitudes toward increasing drone use for commercial operations.
2. Perceptions of drone noise compared to other urban sounds, acceptable noise levels near residences/workplaces, and tolerance for operational frequency.
3. Preferences regarding acceptable distances between drone hubs and sensitive land uses, visual impact concerns, and operational frequency thresholds.
4. Preferences for mitigation strategies and policy approaches, including operational restrictions, technological improvements, and zoning requirements.

These questions were designed to identify the most effective strategies for increasing public acceptance and to guide policy development. Most perception and attitude questions used 10-point Likert scales to capture nuanced responses, while distance and policy preference questions used categorical options based on realistic planning scenarios.

Demographic information, including age, gender, education level, residential setting, household income, and household size, was collected to enable analysis of preference variations across different population segments. The survey instrument was pilot-tested with a small sample of 50 respondents to identify potential issues with question clarity, response options, and survey length before full deployment.

Sampling and Data Collection

Survey respondents are recruited from SurveyMonkey's audience panels, including the Contribute and Rewards programs. Participants opt in to complete surveys and are compensated through non-cash incentives. In the U.S., participants in the Contribute program may donate $0.50 to a charity of their choice for each completed survey. Participants in the Rewards program can earn credits redeemable for gift cards or charitable donations. This approach provides access to a diverse panel of voluntary respondents representative of the U.S. population, incentivized through charitable donations or gift card rewards.

A sample of 1,023 adults was made available by the proprietary research sample provider. This type of sampling was used to ensure representation across demographic categories and residential settings. The sampling frame was designed to achieve geographic distribution across urban, suburban, and rural areas, recognizing that residential setting was expected to be a key variable influencing preferences. The survey was administered online between January and March 2024 using a professional survey platform that ensured data quality through attention checks and validation procedures.

The final sample included 781 respondents (76.3%) who identified as living in urban settings, 97 (9.5%) in suburban areas, and 145 (14.2%) in rural locations. While urban residents were overrepresented relative to national demographics, this distribution reflected the expected concentration of drone operations in urban areas and provided sufficient sample sizes for meaningful analysis across all residential settings. The age distribution was concentrated in the 25-39 age range, with 248 respondents (24.2%) in the 25-29 age group, 378 (37.0%) in the 30-34 age group, and 359 (35.1%) in the 35-39 age group. The gender distribution was nearly equal, with 514 male respondents (50.2%) and 509 female respondents (49.8%).

Regarding education level, 907 respondents (88.7%) reported holding a bachelor's degree, while 75 (7.3%) had graduate degrees. This high educational attainment likely reflects both the online survey methodology and the self-selection of respondents interested in technology topics. For household income, the sample included representation across income brackets, with 396 respondents (38.7%) reporting income in the $50,000-74,999 range and 401 (39.2%) in the $75,000-99,999 range, indicating a predominantly middle-class sample.

Data Analysis Procedures

Survey data were analyzed using descriptive and inferential statistical methods appropriate for the categorical and ordinal nature of most variables. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were calculated for all survey items to identify patterns in preferences and concerns. For scale items, responses were categorized into meaningful groups to facilitate interpretation and comparison, with negative responses defined as scores 1-4, neutral as scores 5-6, and positive as scores 7-10.

Cross-tabulation analyses were conducted to examine relationships between demographic variables and preferences regarding drone hub proximity, noise tolerance, and mitigation strategies. Chi-square tests of independence were performed to identify statistically significant relationships between demographic variables and key preference measures. Chi-square tests were selected as the appropriate statistical method due to the categorical nature of the variables being analyzed and the independence of observations.

For chi-square analyses, expected cell frequencies were examined to ensure they met the minimum requirements for valid testing, with all cells containing expected frequencies greater than five. Statistical significance was established at $p < .05$, with p-values calculated based on the chi-square statistic and corresponding degrees of freedom. Effect sizes were estimated using Cramer's V to assess the practical significance of statistically significant relationships.

Post-hoc analyses were conducted for significant chi-square results to identify specific patterns of association between variables. These analyses involved examining standardized residuals to determine which categories contributed most to significant overall relationships. Data analysis was conducted using SPSS version 29.0, with additional validation performed using R statistical software to ensure the accuracy of results.

Limitations and Validity Considerations

Several limitations should be considered when interpreting the results of this study. First, the survey relied on self-reported perceptions and preferences, which may differ from actual reactions to real-world experiences. Research on stated versus revealed preferences suggests that actual behavior may vary from stated intentions, particularly for novel technologies (Gkartzonikas & Gkritza, 2019). However, stated preference methods are widely accepted for policy research when actual exposure is not feasible.

Second, while the sample size was robust (1,023 respondents), there was an overrepresentation of urban residents (76.3%) and holders of bachelor's degrees (88.7%) relative to the general U.S. population. This demographic skew may limit the generalizability of findings to rural areas and populations with lower educational attainment. However, the urban concentration may be appropriate given that drone operations are expected to be most intensive in urban areas.

Third, as drone technology rapidly evolves, public perceptions may change as familiarity increases and technological improvements address current concerns. The survey captured perceptions at a specific point in time and may not accurately reflect how opinions might evolve with increased exposure to drone operations. Longitudinal research would be valuable for tracking how perceptions change over time.

The validity of the survey instrument was supported through pilot testing and comparison with established measures used in transportation research. Content validity was ensured through expert review and alignment with previous research on public acceptance of transportation technologies—consistent patterns of responses across related questions and logical relationships between variables supported construct validity.

Results

General Attitudes and Familiarity Patterns

The survey revealed moderately positive attitudes toward the increasing use of drones for commercial operations. When asked to rate their feelings on a 10-point scale, where one represented very negative feelings and ten represented very positive feelings, 500 respondents (48.9%) indicated positive perceptions, with scores ranging from seven to ten. Another 371 respondents (36.3%) expressed neutral views with scores of five or six, while 152 (14.9%) reported negative attitudes with scores ranging from one to four. These results suggest that while public acceptance is not universal, a substantial base of support exists for commercial drone operations, which could be expanded through appropriate planning and engagement strategies.

Respondents reported varying levels of familiarity with drones and drone noise, which appeared to influence their overall attitudes toward drone operations. On the 10-point familiarity scale, where 1 indicated no familiarity and 10 indicated very high familiarity, 601 respondents (58.7%) considered themselves moderately to highly familiar with drone technology and its associated noise. Additionally, 444 respondents (43.4%) reported frequently encountering drones in their area of work or residence, indicating that public exposure to drone operations is already substantial in many communities.

Analysis revealed significant demographic differences in general attitudes toward commercial drone operations that have important implications for planning and engagement strategies. Female respondents demonstrated markedly more positive attitudes, with 311 of 509 (61.1%) expressing positive views, compared to 189 of 514 male respondents (36.8%). This difference was statistically significant, $\chi^2(2, N = 1023) = 66.42, p < .001$, challenging conventional assumptions about gender differences in technology acceptance.

Age was also significantly associated with acceptance levels, with younger respondents showing substantially more positive attitudes compared to older age groups. Among respondents aged 25-29, 213 of 248 (85.9%) expressed positive attitudes toward drone operations. This proportion decreased with age, with 172 of 378 respondents aged 30-34 (45.5%) expressing positive views and only 101 of 359 respondents aged 35-39 (28.1%) showing positive attitudes. This relationship was statistically significant, $\chi^2(2, \mathrm{N} = 1023) = 103.06, p < .001$, indicating that acceptance may increase over time as younger, more technology-accepting generations become more prevalent.

Residential settings have a significant influence on acceptance levels, with direct implications for land use planning. Suburban residents showed the highest positive attitudes, with 69 of 97 respondents (71.1%) expressing positive views toward drone operations. Urban residents showed moderate acceptance, with 396 of 781 respondents (50.7%) expressing positive attitudes toward the concept. Rural residents showed the lowest acceptance, with only 35 of 145 respondents (24.1%) expressing positive views. This relationship was statistically significant, $\chi^2(4, N = 1023) = 85.30, p < .001$, indicating that planning approaches may need to be tailored to different residential contexts.

Noise Perception and Tolerance Analysis

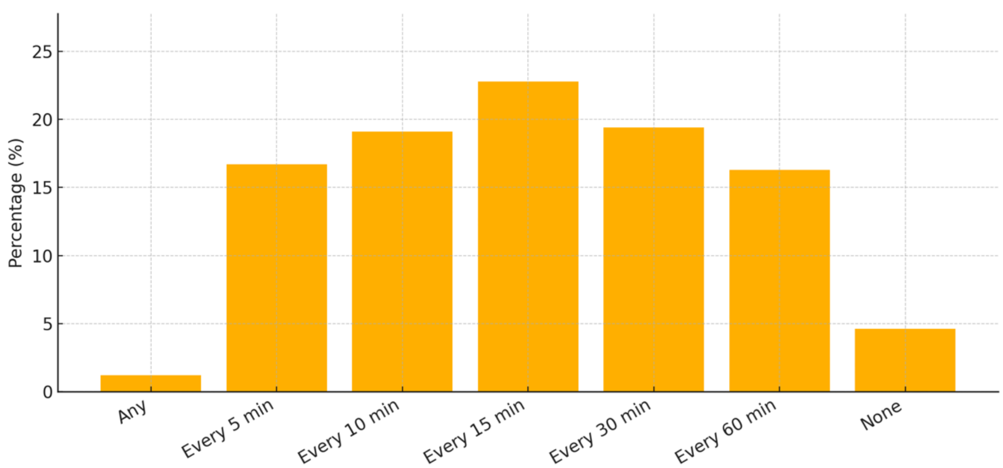
Noise emerged as a significant concern among survey respondents, with clear implications for operational planning and the development of mitigation strategies. When asked to compare drone noise with other urban sounds on a 10-point scale, where one indicated much less annoying and ten indicated much more irritating, 590 respondents (57.7%) rated drone noise as more annoying than other urban sounds, with scores ranging from six to ten. Only 275 respondents (26.9%) considered drone noise less annoying than other urban sounds, with scores from one to four, while 153 (15.0%) rated it as equivalent to other urban sounds, with a score of five. These findings confirm previous research suggesting that the unique acoustic characteristics of drone noise contribute to higher annoyance levels compared to other transportation sounds.

Regarding acceptable noise levels for drone hubs near residences, respondents expressed preferences that varied significantly by residential setting and have direct implications for siting criteria. Among all respondents, 413 (40.4%) indicated they would accept only low background levels of noise comparable to conversation or distant traffic. Another 342 respondents (33.4%) stated that they would accept medium noise levels equivalent to those of adjacent road traffic with passing cars. A smaller group of 205 respondents (20.0%) indicated that they would accept high noise levels similar to those of helicopter flyovers, while 63 respondents (6.2%) stated that no drone noise would be acceptable near their residences.

Noise tolerance varied significantly by residential setting in ways that suggest different regulatory approaches may be appropriate for different community types. Urban residents showed greater tolerance for medium and high noise levels, with 254 of 781 urban respondents (32.5%) accepting medium and 157 (20.1%) accepting high noise levels. In contrast, suburban residents predominantly preferred low noise levels, with 65 of 97 suburban respondents (67.0%) accepting only background noise levels and 23 (23.7%) stating that no drone noise would be acceptable. Rural residents showed a different pattern, with 79 of 145 rural respondents (54.5%) accepting medium noise levels and 48 (33.1%) accepting high noise levels, while none indicated that no drone noise would be acceptable. This variation was statistically significant, $\chi^2(4, N = 1023) = 85.30, p < .001$.

The frequency of operations significantly influenced noise tolerance, with implications for operational restrictions and permit conditions. When asked about the frequency at which drone operations would become annoying at their residences, 233 respondents (22.8%) indicated that operations every 15 minutes would be annoying. In contrast, 198 (19.4%) said operations every 30 minutes would be problematic. Another 195 respondents (19.1%) indicated that operations every 10 minutes would be annoying, and 171 (16.7%) said operations every five minutes would be excessive. A smaller group of 167 respondents (16.3%) indicated that even operations once per hour would be annoying, while 47 (4.6%) stated they would not accept any drone operations at all. Only 12 respondents (1.2%) indicated that any frequency would be acceptable, suggesting that operational frequency limits will be necessary to maintain community acceptance.

Figure 1
Operational Frequency Tolerance

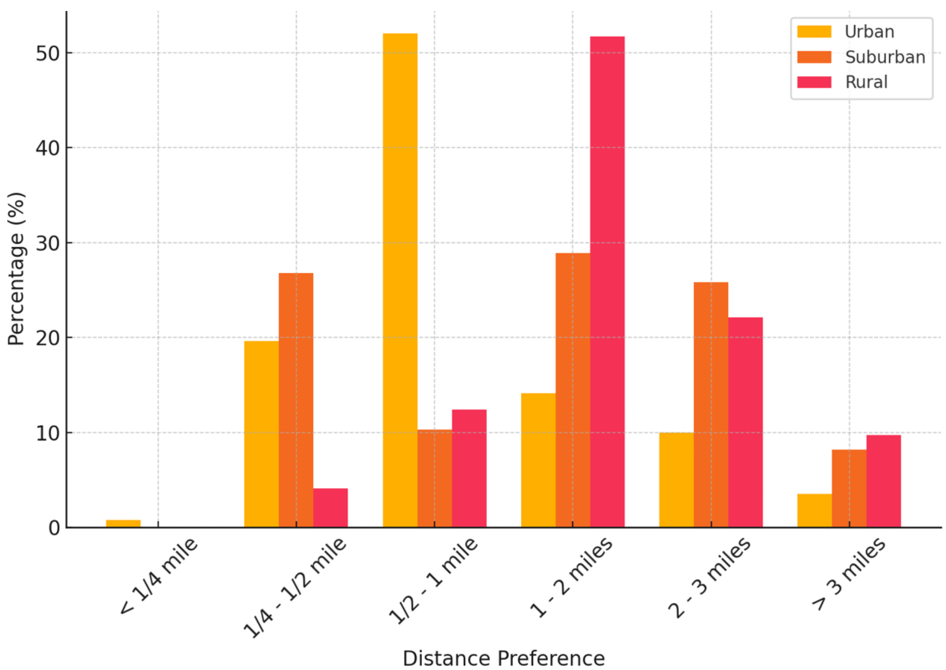


Visual Impact and Proximity Preferences

The survey revealed clear preferences regarding acceptable distances between drone hubs and various land uses, providing specific guidance for zoning and setback requirements. For residential areas, the most common preference was for drone hubs to be located one-half mile to one mile away, with 448 respondents (43.8%) selecting this distance range. The second most common preference was for distances of one to two miles, selected by 213 respondents (20.8%). Another 185 respondents (18.1%) indicated they would accept distances of one-quarter mile to one-half mile, while 86 (8.4%) preferred distances of two to three miles. A smaller group of 78 respondents (7.6%) indicated that they would accept drone hubs within one-quarter mile of their residences, while only 13 (1.3%) preferred distances greater than three miles.

For workplace proximity, respondents generally showed slightly greater acceptance of closer distances compared to residential settings. The most common preference remained one-half mile to one mile, selected by 391 respondents (38.2%). However, there was greater acceptance of closer distances, with 143 respondents (14.0%) accepting distances of one-quarter mile to one-half mile, and 60 (5.9%) accepting distances less than one-quarter mile. Longer distances were also more acceptable for some respondents, with 297 (29.0%) preferring one to two miles and 119 (11.6%) preferring two to three miles.

Figure 2
Distance Preferences by Residential Setting



Chi-square analysis revealed a statistically significant relationship between residential settings and distance preferences that has important implications for context-sensitive planning approaches. The relationship was highly significant, $\chi^2(4, N = 1023) = 227.20$, $p < .001$, with a large effect size indicating substantial practical significance. Urban residents were more accepting of closer drone hub proximities, with 406 of 781 urban respondents (52.0%) preferring a proximity of one-half mile to one mile, and 153 (19.6%) accepting a proximity of one-quarter mile to one-half mile. These preferences suggest that urban areas can accommodate drone hubs with additional minor setback requirements.

In contrast, rural residents preferred greater distances from drone hubs, with 75 of 145 rural respondents (51.7%) selecting one to two miles as their preferred minimum distance and 32 (22.1%) choosing two to three miles. Notably, no rural respondents indicated they would accept drone hubs less than one-quarter mile from their residences, and only six (4.1%) would accept distances of one-quarter mile to one-half mile. These preferences suggest that rural areas may require larger buffer zones to maintain community acceptance.

Suburban residents exhibited a more diverse pattern of preferences, falling between those of urban and rural residents. Among suburban respondents, 28 of 97 (28.9%) preferred distances of one to two miles, while 26 (26.8%) would accept distances of one-quarter to one-half mile. Only 10 suburban respondents (10.3%) preferred a distance of one-half mile to one mile, the distance most preferred by urban residents. These patterns suggest that suburban areas may require intermediate setback requirements that strike a balance between urban efficiency and rural sensitivity.

Policy Preferences and Mitigation Strategies

The majority of respondents supported policy restrictions on drone hub locations near sensitive land uses, providing strong justification for protective zoning measures. When asked whether cities should prohibit the siting of drone hubs near safety and noise-sensitive areas such as residential neighborhoods, schools, and daycare facilities, 1,002 respondents (97.9%) answered affirmatively. Only 21 respondents (2.1%) opposed such restrictions. This near-unanimous support suggests that protective zoning restrictions would have broad public backing and could be implemented without significant political controversy.

When asked about their willingness to accept drone impacts in exchange for conveniences like faster deliveries, responses revealed a substantial portion of the public is open to trade-offs if benefits are communicated. Among all respondents, 549 (53.7%) indicated that they would accept some drone impacts for improved services, while 448 (43.8%) stated that they might be willing to do so, depending on the specific circumstances. Only 26 respondents (2.5%) were firmly opposed to any trade-offs. These results suggest that benefit communication should be a key component of drone hub development strategies and that public acceptance could be increased through clear articulation of service improvements.

Respondents identified several measures that would make drone operations more acceptable, guiding mitigation requirements and operational standards. The most supported measure was reducing noise through technological improvements, endorsed by 645 respondents (63.0%). This strong support suggests that noise performance standards should be a priority in drone hub regulation, and that incentives for quieter technologies could effectively increase their adoption.

Limited drone operating hours received support from 626 respondents (61.2%), suggesting that temporal restrictions on operations could be an effective mitigation strategy for addressing concerns. This finding aligns with research showing that time-of-day restrictions are often more acceptable to communities than absolute activity prohibitions. Increasing public awareness and community involvement in drone policy received support from 573 respondents (56.0%), highlighting the importance of transparent engagement processes in drone hub planning and operation.

Restricting drone flight paths away from sensitive areas was supported by 551 respondents (53.9%), indicating that designated drone corridors could be an effective planning tool for managing community impacts while maintaining operational efficiency. Zoning or land use restrictions for drone hub siting received support from 324 respondents (31.7%), suggesting that while protective zoning has support, operational and technological measures may be more important for acceptance.

Notably, 261 respondents (25.5%) indicated that drone operations were acceptable without additional measures, suggesting that a substantial minority of the public views drone technology favorably. However, only 87 respondents (8.5%) stated that nothing would make drone operations more acceptable, indicating that opposition is not entrenched and that appropriate mitigation measures could address most concerns.

Table 1
Most Supported Mitigation Strategies

Mitigation Strategy	Support (%)
Noise Reduction Technology	63.0
Limited Operating Hours	61.2
Community Involvement	56.0
Flight Path Restrictions	53.9
Zoning/Land Use Controls	31.7
No Additional Measures Needed	25.5

Discussion

Implications for Evidence-Based Drone Hub Siting

The survey results provide clear quantitative guidance for drone hub siting decisions, informing evidence-based land use policies. The strong preference for minimum distances of one-half mile to one mile from residential areas, expressed by 43.8% of respondents, establishes a data-driven baseline for setback requirements that balances operational efficiency with community acceptance. This finding aligns with acoustic research by Torija et al. (2020), who found that drone noise attenuates significantly beyond 800 meters, reducing community impact to levels comparable with ambient urban sound.

The overwhelming support for prohibiting drone hubs near sensitive areas, expressed by 97.9% of respondents, provides compelling justification for protective zoning measures around schools, hospitals, childcare facilities, and residential neighborhoods. This near-unanimous consensus suggests that such restrictions would face minimal political opposition and could be implemented as standard planning practice. The strength of this preference suggests that attempts to site drone hubs near sensitive areas would likely encounter significant community resistance, regardless of proposed mitigation measures.

The statistically significant variation in distance preferences by residential setting provides empirical support for context-sensitive planning approaches rather than uniform standards. Urban residents' greater tolerance for closer proximities, with 52.0% accepting distances of one-half mile to one mile, suggests that urban drone hubs could operate with smaller setback requirements while maintaining community acceptance. This finding is significant, given that urban areas typically face greater land-use pressures and higher property values, making large buffer zones economically challenging.

Conversely, rural residents' preference for greater distances, with 51.7% preferring one to two miles, indicates that rural drone hubs may require larger buffer zones to maintain community support. This preference pattern may reflect rural residents' expectations for greater privacy, lower ambient noise levels, and different land use patterns that make larger setbacks more feasible. The absence of any rural respondents accepting distances less than one-quarter mile reinforces the need for substantial separation between drone operations and rural residences.

Noise Management and Operational Standards

The identification of noise as a dominant concern, with 57.7% of respondents rating drone noise as more annoying than other urban sounds, confirms the critical importance of noise management in the planning and operation of drone hubs. This finding is consistent with previous psychoacoustic research by Schäffer et al. (2021), who identified the unique temporal and spectral characteristics of drone noise as contributing factors to higher annoyance levels compared to other transportation sources.

The preference for limiting drone operations to background noise levels near residences, expressed by 40.4% of respondents, provides specific guidance for noise performance standards in different community contexts. This preference suggests that noise regulations should be calibrated to ambient sound levels rather than using absolute decibel limits, allowing for appropriate standards in different urban, suburban, and rural environments. The significant variation in noise tolerance by residential setting further supports this approach, with urban residents showing greater acceptance of medium and high noise levels compared to suburban residents, who predominantly preferred background levels.

The finding that operational frequency significantly influences acceptance, with only 1.2% of respondents accepting unlimited operational frequency, provides essential guidance for permit conditions and operational restrictions. The most commonly acceptable frequency of operations, every 15 minutes, preferred by 22.8% of respondents, suggests that drone hub permits should include maximum hourly operation limits that vary based on proximity to sensitive receptors and time of day. This approach would provide operational flexibility while maintaining community acceptance.

The significant relationship between residential settings and noise tolerance has important implications for developing differentiated noise standards. Urban residents' greater tolerance for medium noise levels (32.5% acceptance) and high noise levels (20.1% acceptance) suggests that urban drone hubs could operate under less restrictive noise standards than those in suburban or rural areas. This differentiation would reflect both the higher ambient noise levels in urban areas and the greater density of development that may require more intensive drone operations.

Effective Mitigation Strategies and Technology Requirements

The strong public support for noise reduction technology, endorsed by 63.0% of respondents, provides clear direction for regulatory requirements and incentive programs. This finding suggests that land use regulations should include performance standards for drone noise emissions, potentially requiring quieter drone models or noise-reducing modifications for operations in areas with high residential density. The preference for technological solutions over operational restrictions indicates that the public is willing to accept drone operations if appropriate technology is employed to minimize impacts.

Research by Intaratep et al. (2016) has shown that modifications to propeller design and shrouding can reduce drone noise by 10-15 decibels without significantly compromising performance. The survey results suggest that such noise reduction technologies should be required for drone hub operations, particularly those closer to residential areas. This approach would allow for more flexible siting while addressing the primary community concern about noise impacts.

The substantial support for limited operating hours, expressed by 61.2% of respondents, indicates that temporal restrictions represent an effective and acceptable mitigation strategy. This finding aligns with research by Torija et al. (2020), showing that community acceptance of drone noise varies significantly by time of day, with evening and nighttime operations generating substantially higher complaint rates. Operational restrictions during sensitive periods could be incorporated into permit conditions, allowing more intensive operations during less sensitive daytime hours.

The support for flight path restrictions, endorsed by 53.9% of respondents, provides empirical justification for establishing designated drone corridors as part of comprehensive land use planning. Research by Pongsakornsathien et al. (2020) demonstrated that well-designed corridor systems could reduce noise exposure to residential areas by up to 40% compared to unrestricted flight patterns. The survey results suggest that such corridors would be publicly acceptable and could effectively manage cumulative impacts from multiple drone operations.

The high level of support for community involvement in drone policy development, expressed by 56.0% of respondents, confirms the importance of transparent engagement processes in gaining and maintaining public acceptance. This finding is consistent with research by Kuzma et al. (2021), who documented significant improvements in public acceptance following robust community engagement programs. The survey results suggest that engagement should be viewed not merely as a procedural requirement but as a substantive strategy for improving policy outcomes and building long-term community support.

Demographic Considerations and Targeted Engagement

The significant differences in acceptance across demographic groups revealed by the chi-square analyses have essential implications for engagement strategies and policy development. The higher acceptance among female respondents, with 61.1% expressing positive attitudes compared to 36.8% for males, challenges conventional assumptions about gender differences in technology acceptance and suggests that engagement strategies should avoid gender stereotypes that might assume male audiences are more receptive to technology-focused messages.

The strong relationship between age and acceptance, with 85.9% of respondents aged 25-29 showing positive attitudes compared to 28.1% of those aged 35-39, suggests that acceptance may increase over time as younger, more technology-accepting generations become predominant. However, this finding also indicates that current planning approaches should address the concerns of older residents who may be more skeptical of drone operations. Engagement strategies should acknowledge these generational differences and provide information tailored to address the specific concerns of different age groups.

The variation in acceptance by residential settings has direct implications for tailoring engagement approaches to different community contexts. Suburban residents' high acceptance levels (71.1% positive attitudes) suggest that suburban communities may be more receptive to proposals for drone hubs. In comparison, the lower acceptance rate among rural residents (24.1% positive attitudes) suggests that rural engagement efforts may need to focus more heavily on addressing concerns and demonstrating benefits. Urban residents' moderate acceptance levels (50.7% positive attitudes) suggest that urban engagement should focus on optimizing site selection and operational parameters rather than merely building basic acceptance.

The finding that 53.7% of respondents would accept drone impacts in exchange for conveniences like faster deliveries indicates that benefit communication should be a key component of drone hub development strategies. This result suggests that public acceptance could be increased through clear articulation of service improvements, environmental benefits such as reduced vehicle emissions, and economic advantages, including job creation and reduced delivery costs. However, the substantial percentage of respondents (43.8%) who indicated they might be willing to accept trade-offs suggests that acceptance is conditional and depends on the benefits offered and impacts experienced.

Policy Framework Development and Implementation

The survey results provide an empirical foundation for developing comprehensive policy frameworks that strike a balance between innovation and community protection. The strong support for prohibitions near sensitive areas, along with a preference for specific setback distances and operational restrictions, suggests that effective policies should combine exclusionary zoning with performance-based standards that allow for operational flexibility within appropriate parameters.

The significant relationships between demographic variables and preferences suggest that policy frameworks should incorporate flexibility to address diverse community contexts, rather than applying uniform standards across all areas. This approach aligns with broader trends in planning toward context-sensitive design and place-based policies that recognize local variations in needs, preferences, and constraints (Freeman & Freeland, 2022).

The identification of multiple effective mitigation strategies suggests that policy frameworks should offer menu-based approaches, allowing operators to choose among different mitigation options based on site-specific conditions and community preferences. This flexibility could improve operational efficiency and community acceptance by providing customized solutions that address local concerns while maintaining viable operations.

The temporal dimensions of acceptance, reflected in support for limited operating hours and sensitivity to operational frequency, indicate that policy frameworks should incorporate time-based restrictions and phased implementation approaches. Initial operations could be limited to less sensitive periods and gradually expanded based on community experience and demonstrated compliance with performance standards.

Policy Guidelines and Recommendations

Context-Sensitive Setback Requirements

Based on the survey findings, land use regulations should establish minimum setback requirements between drone hubs and sensitive receptors that reflect the significant variation in community preferences across different residential settings. The regulations should recognize that urban areas, where 52.0% of respondents preferred distances of one-half mile to one mile, can accommodate drone hubs with smaller buffer zones due to higher ambient noise levels, greater development density, and a higher acceptance of technological solutions. Urban drone hubs should be permitted with a minimum setback of one-quarter to one-half mile from residential areas, provided they meet enhanced noise performance standards and incorporate the required technological mitigation measures.

Rural areas, where 51.7% of respondents preferred distances of one to two miles, and no respondents accepted distances less than one-quarter mile, require substantially larger buffer zones to maintain community acceptance. Rural drone hub regulations should establish minimum setbacks of one to two miles from residential areas and sensitive facilities, reflecting the expectations of rural residents for greater privacy, lower ambient noise levels, and more intense concerns about technological intrusion. These larger setbacks are generally more feasible in rural areas due to lower land values and less intensive development patterns.

Suburban areas, which showed intermediate preferences, with 28.9% of respondents preferring one to two miles and 26.8% accepting one-quarter to one-half mile, should be governed by intermediate setback requirements of one-half to one mile. This approach recognizes suburban communities' position between urban and rural contexts, characterized by moderate-density development and expectations for residential quiet that fall between urban and rural standards.

High-frequency drone hub operations, defined as facilities generating more than 20 flights per hour, should be subject to increased setback requirements, regardless of the residential setting. These intensive operations should maintain a minimum of one mile from residential areas to address the cumulative noise impacts and visual intrusion associated with frequent operations. Lower-intensity operations generating fewer than ten flights per hour could operate with reduced setbacks, provided they meet enhanced technological requirements and operational restrictions.

Comprehensive Noise Performance Standards

Since 57.7% of respondents rated drone noise as more annoying than other urban sounds, noise performance standards should be central to drone hub regulation and calibrated to local ambient conditions rather than using uniform decibel limits. Urban drone hubs should meet maximum ambient background sound levels plus 10 decibels at residential property boundaries, recognizing that urban residents have a greater tolerance for moderate noise increases and higher baseline ambient levels.

Suburban drone hubs should meet more stringent standards, with ambient background noise plus 5 decibels at residential boundaries, reflecting suburban residents' strong preference for low noise levels, as 67.0% accept only background levels. Rural drone hubs should meet the most restrictive standards of ambient background plus 3 decibels, acknowledging rural residents' expectations for minimal noise intrusion and typically lower ambient sound levels.

The noise standards should incorporate temporal variations that reflect community preferences for operational restrictions. Daytime operations, between 7:00 AM and 7:00 PM, can operate under standard noise limits. Evening operations, between 7:00 PM and 10:00 PM, should meet reduced limits of 5 decibels below daytime standards. Nighttime operations between 10:00 PM and 7:00 AM should be prohibited within one mile of residential areas, based on the strong support (61.2%) for limited operating hours and research showing increased sensitivity to noise during sleeping hours.

Drone hub operators should be required to conduct quarterly noise monitoring at representative residential locations and provide the public with access to the monitoring data through online dashboards. Operators exceeding noise limits should face progressive enforcement measures, including operational restrictions, required technology upgrades, and potential permit revocation for repeated violations. This monitoring approach ensures ongoing compliance while providing transparency that can help maintain community trust.

Operational Frequency and Timing Restrictions

The survey finding that only 1.2% of respondents found unlimited operational frequency acceptable provides strong justification for establishing maximum operational limits that vary based on proximity to sensitive receptors and time of day. Drone hubs within one-quarter mile of residential areas should be limited to a maximum of four operations per hour during daytime periods, reflecting the need for substantial operational restrictions when facilities are close to residential areas.

Facilities located one-quarter to one-half mile from residential areas should be permitted a maximum of eight operations per hour during daytime periods, while those located one-half to one mile away should be allowed a maximum of twelve operations per hour. Drone hubs more than one mile from residential areas could operate with higher frequency limits determined through case-by-case analysis based on site-specific noise modeling and community input.

Evening operations between 7:00 PM and 10:00 PM should be limited to 50% of daytime operational limits to address increased sensitivity during nighttime quiet periods. Weekend operations should be subject to the same restrictions as weekday operations. Still, operators should be encouraged further to limit Saturday and Sunday morning operations before 9:00 AM to respect extended sleep periods that are common on weekends.

The operational frequency limits should be calculated on a rolling hourly basis rather than fixed hourly periods to prevent the concentration of operations during specific time windows that could create temporary noise impacts exceeding community tolerance. Operators should maintain detailed flight logs that document compliance with frequency limits and make this information available for regulatory review and public inspection upon request.

Technology Requirements and Innovation Incentives

The strong support for noise reduction technology, expressed by 63.0% of respondents, justifies requiring the best available noise reduction technologies for all drone hub operations. All drones operating from approved hubs should incorporate noise-reducing propeller designs, motor shrouding, or other technologies that achieve at least 10-decibel noise reduction compared to standard configurations. Operators should be required to demonstrate compliance with technology requirements through certified testing and periodic verification.

Remote ID compliance should be mandatory for all drone hub operations to enhance traceability and accountability, building on existing FAA requirements while ensuring local oversight capabilities are in place. All hub-based operations should require Advanced collision avoidance systems to minimize safety risks and address public concerns about operational safety. These systems should meet performance standards exceeding basic FAA requirements and include autonomous emergency landing and obstacle avoidance capabilities.

Drone hub permits should include requirements for progressive technology improvement, with operators required to adopt improved noise reduction technologies as they become commercially available. Regulatory agencies should establish technology assessment programs that evaluate emerging noise reduction innovations and update requirements in response to technological advancements. This approach ensures that the community benefits from ongoing innovation while providing operators with clear expectations for adopting new technologies.

Incentive programs should be established to encourage the adoption of advanced noise reduction technologies beyond minimum requirements. These incentives could include reduced setback requirements for operators employing superior technology, expedited permitting for facilities meeting enhanced technology standards, or fee reductions for operations demonstrating exceptional noise performance. Such programs would accelerate technology adoption while providing regulatory flexibility for operators investing in community benefits.

Community Engagement and Transparency Framework

The support for community involvement expressed by 56.0% of respondents indicates that engagement should be viewed as a substantive requirement rather than a procedural formality. Drone hub proposals should include comprehensive community engagement programs that begin during the initial site selection process and continue throughout the facility's operation. Preapplication engagement should consist of public information sessions, community surveys to assess local concerns and preferences, and formal opportunities for public input on proposed facility design and operational parameters.

During the permitting process, applicants should be required to demonstrate responsive design changes based on community input and to address specific concerns raised during public engagement. Ongoing engagement during operations should include regular community meetings, accessible complaint resolution procedures, and annual reporting on operational performance and community benefits. This sustained engagement helps maintain community support and provides opportunities to address emerging issues before they become significant problems.

Public access to operational information should be ensured through online dashboards that provide real-time data on flight operations, noise monitoring results, safety performance, and complaint resolution. This transparency helps build community trust while providing accountability mechanisms that promptly address concerns and issues. Regular community advisory meetings should be established to provide ongoing forums for community input and collaborative problem-solving between operators and residents.

Benefit-sharing mechanisms should be developed to ensure communities hosting drone hubs receive tangible benefits from these operations. These mechanisms could include local hiring preferences for drone hub employment, community service applications such as emergency supply delivery or infrastructure inspection, educational partnerships with local schools and universities, or investment in public amenities in affected neighborhoods. Such programs help ensure that drone hubs benefit not only operational efficiency but also community improvements.

Implementation Strategy and Adaptive Management

Given the emerging nature of drone technology and evolving public perceptions, regulatory approaches should incorporate adaptive management principles that allow for policy refinement based on operational experience and changing conditions. Initial drone hub approvals should include sunset provisions that require a comprehensive performance review and reauthorization after 18 to 24 months of operation. These reviews should assess actual noise impacts, community satisfaction, operational compliance, and technology performance to inform decisions regarding permit renewal and potential modifications to operational parameters.

Performance-based regulatory approaches should be prioritized over prescriptive requirements where possible, focusing on measurable outcomes such as noise levels, complaint frequency, safety records, and community satisfaction rather than specific operational procedures. This approach allows operators to innovate while ensuring community protection objectives are met. Regular monitoring and assessment should document actual performance against established standards and provide data for regulatory adjustment as needed.

Regional coordination mechanisms should be established to ensure consistent standards across jurisdictions and prevent regulatory fragmentation, which could complicate operations and reduce the effectiveness of regulatory efforts. Multi-jurisdictional planning frameworks should be developed for metropolitan areas where drone operations may cross municipal boundaries, ensuring coordinated approaches to airspace management, corridor designation, and cumulative impact assessment.

Pilot programs should be established in volunteer communities to test regulatory approaches and gather empirical data on community impacts and acceptance levels. These programs should include comprehensive monitoring of noise levels, community attitudes, economic impacts, and operational performance to inform broader policy development and implementation. Successful pilot programs can serve as models for wider implementation while building public confidence in regulatory effectiveness.

Conclusion

This comprehensive survey of 1,023 U.S. residents provides robust empirical evidence for developing land use policies and operational guidelines for drone hub siting that balance technological advancements with community acceptance. The research reveals clear patterns in public preferences that can inform evidence-based policy development rather than relying solely on theoretical frameworks or expert opinion. The findings demonstrate that while public acceptance of drone operations is not universal, substantial support exists that can be expanded through appropriate planning, siting, and operational approaches.

The overwhelming consensus, expressed by 97.9% of respondents, supporting prohibitions near sensitive areas establishes a clear foundation for protective zoning measures around schools, hospitals, childcare facilities, and residential neighborhoods. This near-unanimous preference provides compelling justification for exclusionary zoning, which would face minimal political opposition and could be implemented as a standard planning practice. The strength of this consensus indicates that attempts to locate drone hubs near sensitive areas would likely encounter significant community resistance regardless of proposed mitigation measures.

The significant variation in distance preferences by residential setting, confirmed through chi-square analysis with strong statistical significance, provides empirical support for context-sensitive planning approaches rather than uniform standards. Urban residents' greater acceptance of closer proximities suggests that urban drone hubs can operate with smaller setback requirements while maintaining community support, which is particularly important given the pressures on urban land use and the higher property values. Rural residents' clear preference for greater distances indicates that rural areas require larger buffer zones that reflect expectations for privacy and lower ambient noise levels.

The identification of noise as the dominant community concern, with 57.7% of respondents rating drone noise as more annoying than other urban sounds, confirms the critical importance of noise management in policy development. The survey results provide specific guidance for developing noise performance standards calibrated to local ambient conditions and residential settings rather than using uniform limits. The significant variation in noise tolerance across urban, suburban, and rural areas supports differentiated approaches that recognize varying community expectations and acoustic environments.

The strong support for multiple mitigation strategies guides the development of comprehensive policy frameworks that address community concerns while maintaining operational viability. Noise reduction technology received the highest support at 63.0%, followed by limited operating hours at 61.2% and community involvement at 56.0%. These findings suggest that effective policies should combine technological requirements, operational restrictions, and engagement processes rather than relying on single approaches.

The significant demographic differences in acceptance levels revealed through statistical analysis have important implications for engagement strategies and the implementation of policies. The higher acceptance among female respondents and younger age groups challenges conventional assumptions, suggesting that engagement approaches should be carefully designed to address the concerns of different demographic segments. The substantial portion of respondents (53.7%) willing to accept drone impacts in exchange for clear benefits indicates that benefit communication should be central to drone hub development strategies.

Contributions to Planning Practice and Policy Development

This research makes several important contributions to planning practice and policy development for emerging transportation technologies. First, it provides quantitative data on public preferences that can inform evidence-based policy development rather than relying solely on expert opinion or theoretical frameworks. The specific distance preferences, noise tolerance levels, and mitigation strategy rankings provide concrete parameters that can be incorporated into zoning codes, operational permits, and regulatory standards.

Second, the demonstration of significant variation in preferences across demographic groups and residential settings provides empirical support for context-sensitive planning approaches that recognize local differences rather than applying uniform standards. This finding has broader implications for planning practice, extending beyond drone infrastructure, and supports more nuanced approaches to transportation and land use planning that consider community characteristics and preferences.

Third, identifying effective mitigation strategies and their relative levels of public support provides guidance for prioritizing regulatory requirements and allocating resources. The strong preference for technological solutions over operational restrictions suggests that investing in noise reduction technology may be more effective than implementing restrictive zoning in achieving community acceptance.

Limitations and Future Research Directions

While this study provides valuable insights into public preferences regarding drone hub siting, several limitations that suggest future research directions should be acknowledged. The reliance on stated preferences without actual exposure to drone operations may not fully predict reactions to real-world implementations. Longitudinal research tracking how opinions change after the implementation of a drone hub would provide valuable insights into the accuracy of stated preferences versus actual community responses.

The demographic composition of the sample, although substantial in size, showed an overrepresentation of urban residents and college-educated respondents compared to national demographics. Future research should prioritize achieving more representative samples, particularly including greater representation of rural residents and diverse educational backgrounds. Additionally, the concentration of respondents in specific age groups suggests that broader age representation would strengthen the generalizability of findings.

Rapid technological development in drone operations means that public perceptions may evolve as technology improves and familiarity increases. Future research should track how attitudes change as drone operations become more common and technological improvements address current concerns about noise, safety, and privacy. Comparative studies examining communities with and without drone operations could provide insights into how actual exposure influences preferences.

Field experiments examining community responses to different noise levels, operational frequencies, and mitigation measures would provide more precise data for policy development. Such research could test the effectiveness of specific mitigation strategies and refine operational parameters based on measured community responses, rather than relying on stated preferences.

An economic impact analysis examining the benefits of drone hub operations, including job creation, service improvements, cost savings, and environmental benefits, would provide important context for understanding the full implications of these facilities. Research documenting both the costs and benefits would help communities make informed decisions about drone hub proposals and could inform benefit-sharing mechanisms.

Implications for Sustainable Transportation Infrastructure Development

The findings of this research have broader implications for the development of sustainable transportation infrastructure in an era of rapid technological change. The study demonstrates the importance of proactive community engagement and evidence-based policy development in facilitating the adoption of beneficial technologies while protecting community interests. The success of drone infrastructure implementation may serve as a model for other emerging transportation technologies, including autonomous vehicles, urban air mobility, and hyperloop systems.

The research highlights the critical role of noise management in community acceptance of new transportation technologies, suggesting that acoustic considerations should be central to infrastructure planning rather than treated as secondary concerns. The preference for technological solutions over operational restrictions indicates that investment in technology development may be more effective than regulatory limitations in achieving both innovation goals and community acceptance.

The demonstrated importance of context-sensitive approaches suggests that sustainable infrastructure development requires careful attention to local conditions, preferences, and constraints rather than uniform implementation strategies. This finding supports broader trends toward place-based planning and community-centered development approaches that recognize local variation and prioritize community input in decision-making processes.

The land use guidelines and policy recommendations developed through this research provide a framework for communities to proactively plan for the integration of drone hubs, rather than reactively responding to development proposals. By establishing clear expectations for siting, operations, and community engagement based on empirical evidence of public preferences, these guidelines can facilitate responsible technological advancement while protecting community interests and enhancing quality of life. The successful implementation of these evidence-based approaches may serve as a model for managing other emerging technologies that will continue to transform transportation systems and urban development patterns.

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Plan Continuation Error and the Five Hazardous Attitudes: Can Your Hazardous Attitude Lead You into a Dangerous Place?

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The purpose of this paper is to explore and analyze the concepts of plan continuation bias and the five aviation hazardous attitudes. Both phenomena have significant implications for aviation safety and decision making. This paper will examine the impact that pilot hazardous attitudes have on plan continuation bias and plan continuation error. Multiple aviation accidents and incidents are used in this examination.

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Introduction

The human element remains the foremost contributor to aviation incidents and accidents with human error leading the way of contributing factors (Velazquez et al., 2015). Decisions made by pilots have the potential to lead to a successful outcome or a disastrous result. Fundamental to a pilot's decision making is his or her attitude towards what they are doing. An attitude impacts how we respond to an event; it is a predisposition that drives us toward a response (FAA, 2004; FAA, 2009; Nunez et al., 2019). The FAA has identified five Hazardous Attitudes, and these attitudes can negatively impact our ability to make good decisions (Wetmore & Lu, 2006). The FAA also identifies operational pitfalls. These are decision-making traps into which pilots can fall. One such pitfall is called "Get-There-Itis", defined by the FAA as a "tendency, common among pilots, clouds the vision and impairs judgement by causing a fixation on the original goal or destination combined with a total disregard for any alternative course of action" (FAA, 1991, p. 3). The purpose of this paper is to examine the relationship between the five hazardous attitudes and the operation pitfall, Plan Continuation Bias, which is also known as Get-There-Itis. This examination is accomplished by reviewing accidents and incidents where plan continuation bias was present, and identifying the hazardous attitude demonstrated by the pilot or crew.

Literature Review

The FAA provides Advisory Circular (AC) 60-22, which addresses Aeronautical Decision Making (ADM). The FAA's definition of ADM is "a systematic approach to the mental process used by aircraft pilots to consistently determine the best course of action in response to a given set of circumstances" (FAA, 1991, p. ii). Within ADM, an attitude can influence the mental process involved in determining the best course of action. A hazardous attitude like those identified by the FAA can lead a pilot to make a poor decision, compromising the safety of flight.

Plan Continuation Bias

One decision-making pitfall is Plan Continuation Bias. This bias is defined as a desire to continue a plan in the face of obvious cues indicating that continuing the pre-made plan presents significant challenges or danger (Orasanu et al., 2001). Decision making begins long before a flight departs, but those decisions are not made in a vacuum. The purpose of the flight, or the mission of the flight, can influence a pilot's decision-making process and can influence the go/no-go decision as well as decisions impacting the continued conduct of that flight. A flight to get lunch may carry a very low burden of completion. If the conditions are marginal, the flight can wait until another day. A flight to deliver a human organ for transplant bears a very high burden to complete, and the pilot may feel compelled to attempt or continue the flight in the face of hazardous conditions. Once airborne, and the planned flight has been implemented, pilots can fall into the trap of plan continuation for different reasons. Pilots' hazardous attitudes can contribute to the desire to continue a flight or an approach even when faced with cues indicating that the plan should be modified.

According to Orasanu et al. (2001), two components affect decisions made by pilots: situation assessment and choosing a course of action. Pilots can make situation assessment errors for several reasons. Mosier et al. (2012) explain that situation assessment can be influenced by many factors. In some situations, the cues defining the situation can be interpreted incorrectly; they may be misdiagnosed, even ignored entirely. In decision-making, a pilot must first define the problem and then complete an assessment of the risk that the problem poses and the time available to solve it. Considering the options available, the pilot then chooses a course of action to address the problem. A decision error can occur at this point if the pilot incorrectly assesses the risk, which can cause the pilot to choose an incorrect course of action (Orasanu et al., 2001).

Plan continuation bias (sometimes plan continuation error) is often referred to as get-there-itis; that compulsion to complete the flight even in the face of obvious changing conditions that exceed the pilot's or aircraft's capabilities (Orasanu et al., 2001). Plan continuation bias can lead to a pilot passing opportunities to divert or change the planned flight because of the compulsion to see the original plan through to completion. While plan continuation bias is often referred to as get-there-itis, it can encompass situations beyond the desire to get to the planned destination. Examples of this decision-making pitfall can include continuing an unstable approach, or an approach with convective activity near the airport, and others (Mosier et al., 2012).

Five Hazardous Attitudes

The FAA identifies five attitudes that are hazardous to safe operations in aviation. These Hazardous Attitudes are *macho, impulsivity, resignation, invulnerability, and anti-authority.* These attitudes can impact the decisions pilots make, potentially leading to incidents and accidents. Advisory Circular (AC) 60-22 (FAA, 1991) discusses aeronautical decision-making (ADM) and includes a hazardous attitude inventory. Completing the inventory will identify an individual pilot's top hazardous attitudes.

A pilot who exhibits a hazardous, macho attitude is one who shows off or wants to show that they are better than others. They will attempt to prove that they are better by taking risks to impress others; they may exhibit a "can-do" attitude. While this hazardous attitude is commonly thought to influence males, women can also exhibit this trait (Nunez et al., 2019). Impulsivity is the hazardous attitude that causes a pilot to decide to do something, anything, as quickly as possible (FAA, 1991). These pilots do not use a formal decision-making process; they simply do the first thing that comes to mind. Resignation is a hazardous attitude that leads a pilot to believe that they have little impact on the outcome of a situation; they think, "What's the use?". These pilots attribute outcomes to luck or happenstance (FAA, 1991). The invulnerable pilot believes that accidents happen to other people, not them. Pilots with an invulnerable, hazardous attitude recognize that accidents happen, but they happen to others. Because of this attitude, invulnerable pilots are prone to taking additional risks (FAA, 1991). The pilot exhibiting anti-authority is a rule breaker, one who believes that rules are for others; their mindset is one of independence; they do not want to be told what to do. Pilots with this attitude view rules, standard operating procedures (SOPs), and regulations as unnecessary, and as a result, they do not abide by them (Neff, 2022; Nunez et al., 2019). The anti-authority pilot may be aware of company standard operating procedures (SOPs) but, for any of several reasons, chooses not to follow those procedures (FAA, 1991). These attitudes lead to poor judgment, and what can follow poor judgment is poor decision-making. Poor decision-making can lead to disastrous results.

For each hazardous attitude, the FAA (1991) identifies an antidote (Table 1). The antidote is intended to act as a reminder to the pilot that hazardous attitudes exist and that they can be countered by redirecting that attitude in a way that leads to correct actions. The FAA explains the steps for applying an antidote. The process begins with recognition of the hazardous thought and continues with stating the antidote. This process should be practiced until the correct antidote can be recalled immediately.

Table 1

Five Hazardous Attitudes and the Antidotes

Hazardous Attitude	Antidote
Macho	Taking chances is foolish.
Impulsivity	Not so fast. Think first
Resignation	I'm not helpless. I can make a difference.
Invulnerability	It could happen to me.
Anti-Authority	Follow the rules. They are usually right.

The Impact of Hazardous Attitudes on Decision-Making

Wetmore and Lu (2006) conducted a study examining the effect of hazardous attitudes on pilot decision making and Crew Resource Management (CRM) skills. Their findings suggest that hazardous attitudes, in general, can lead pilots to accept more risky flights, make pilots more prone to making bad decisions, and make them more likely to make errors. In a review of general aviation fatal accidents, the authors identified different hazardous attitudes in National Transportation Safety Board (NTSB) factual reports. Of 50 randomly selected NTSB reports reviewed, 20, or 40%, the authors found three hazardous attitudes demonstrated by the accident pilot. In 37 accidents, multiple hazardous attitudes were present (Wetmore & Lu, 2006).

The authors examined the effect of multiple hazardous attitudes on decision making and CRM skills and found that those pilots exhibiting multiple hazardous attitudes were willing to accept twice the number of risk factors, made five times the number of poor decisions, and reduced the pilots' use of resources. The authors found evidence that suggested that as the number of hazardous attitudes demonstrated by an accident pilot increased, the number of bad decisions made by that pilot increased (Wetmore & Lu, 2006).

According to Wetmore and Lu (2006), hazardous attitudes have a detrimental impact on evaluating risk, making good decisions, and using resources available to a pilot. The authors describe a sequence of events that can lead to the type of accident they reviewed. The sequence begins with a pilot, influenced by their hazardous attitudes, knowingly accepts a high-risk flight. When conditions during the flight begin to deteriorate, the pilot's hazardous attitudes impact decision-making, leading to poor decisions. In the final step in this sequence, because of the hazardous attitudes present, the pilot is unable to make full use of all available resources, impacting the outcome of the flight (Wetmore & Lu, 2006).

Decision-making is a fundamental skill for all pilots that relies on situational awareness, critical thinking skills, and risk management. Pilots continue to make poor decisions, sometimes in the face of what others would identify as obvious indications that a better way forward exists. The hazardous attitudes influence our decision-making, and not for the better.

Examples of Hazardous Attitudes Contributing to Plan Continuation Error

The following are aircraft accidents where a plan continuation error is evident. In each of these accidents, at least one aviation hazardous attitude was present and was identified. Often, multiple hazardous attitudes can be identified.

Macho

Orasano et al. (1997) describe the crash of a US Air Force CT-43 aircraft that killed then-Secretary of Commerce Ron Brown. The CT-43 is the military version of the Boeing 737-200 aircraft. Multiple issues were identified as contributory to the accident. The aircraft was not properly equipped with the required avionics to be authorized to conduct the instrument approach; unauthorized, civilian approach charts were used, and the crew was not adequately trained to read the charts. The crew executed the approach, knowing they were not authorized to conduct the instrument procedure. The crew continued with their original plan to get the aircraft and its passengers to the intended destination. With the prevailing weather conditions, the aircraft instrumentation, and the charts available, the approach should never have been attempted. The authors continue that flight crews can be rewarded for exhibiting a "can-do" attitude. This mindset exemplifies the Macho hazardous attitude. Their macho, hazardous attitude led them to make a series of decisions, to choose a course of action, and ultimately to continue the flight as planned to complete the mission.

Impulsivity

A student pilot working towards his Private Pilot Certificate experienced a sudden gust of wind while attempting a normal landing. The student overcompensated, panicked, and pitched down aggressively in an attempt to get the airplane on the runway. The nosewheel of the aircraft contacted the runway first, ultimately leading to a propeller strike. The aircraft sustained minor damage, and the student was unhurt. During a post-incident interview with the student, he stated that when he encountered the gust, his initial reaction was to get the airplane on the runway quickly. He was panicked. The student stated, "Looking back at it, I realize I was impulsive, I should have done a go-around. I just wanted to get it on the ground" (Anonymous, personal communication, 2019).

This student's experience is not unique, but it demonstrates the hazardous attitude of impulsivity. The student wanted to do something, anything, to get out of the situation he found himself in. He continued a botched landing attempt, trying to get the airplane on the runway when the best course of action was to execute the go-around. In this case, he chose a course of action that was incorrect. The student learned a valuable, though costly, lesson.

Resignation

An example of resignation can be observed in the crash of Empire Airlines Flight 8284. In this case, resignation observed in a first officer contributed to the outcome. The Aerospatiale Alenia ATR 42-320 was conducting an instrument approach into Lubbock, Texas, during night, instrument meteorological conditions. The accident sequence began with the first officer acting as the pilot flying, and appropriate briefings were conducted, including a review of the missed approach procedure. The flight encountered icing conditions during the descent and approach. The Lubbock approach controller advised the flight crew that the visibility at the airport was 2 miles with light freezing drizzle and mist. The first officer called for the flaps to be set to 15 degrees and for the landing gear to be extended. A flap asymmetry occurred with the left flap partially extending and the right flap remaining in the up, retracted position. The flap asymmetry caused the autopilot to deflect the yoke approximately 20 degrees to counter the flap condition. Because of a perceived acceleration, the first officer reduced power on both engines, and the airspeed subsequently reduced from 160 to 125 knots. At this point, several things happened: the aural stall warning sounded, the stick shaker activated, and the autopilot disconnected. The first officer increased engine power to approximately 70% and began manually flying the aircraft. They were 900 feet above ground level. The first officer asked the captain, "Should I go around?" to which the captain replied, "No, keep descending" (NTSB, 2011, p.5).

The NTSB accident report indicates that the first officer made another comment to the captain, and that the first officer's voice sounded strained. The captain stated he was surprised to see the first officer manually flying the airplane, could see she was struggling with the controls, and asked if the first officer wanted him to finish the approach. The first officer accepted. During the last portion of the approach, the airspeed deteriorated, the stall warning systems activated, and the aircraft impacted the ground short of the runway and slid (NTSB, 2011).

A combination of factors led to this outcome. This crew chose a course of action to continue the approach with a flap anomaly in icing conditions. The first officer's inquiry about the go-around indicates that she felt that was the appropriate course of action, but she was countermanded by the captain, and at this point, she demonstrated her resignation. The crew demonstrated a plan continuation error by not conducting a go-around, which would have allowed them time to troubleshoot the flap anomaly and devise an appropriate plan for the conclusion of the flight.

Invulnerability

American Airlines Flight 1420, a McDonnell Douglas DC-9-82 (MD-82), overran runway 04R during landing at Little Rock National Airport in Little Rock, Arkansas, on June 1, 1999. The captain and 10 passengers were killed, 105 passengers and five crew were injured, and the aircraft was destroyed by impact forces and post-impact fire. In their final report, the NTSB stated that the probable causes of the accident were "the flight crew's failure to discontinue the approach when severe thunderstorms and their associated hazards to flight operations had moved into the airport area…" (NTSB, 2001, p xii). The accident report continues that the crew continued the approach to land when the maximum crosswind component limitation was exceeded, the crew was fatigued and experiencing situational stress (NTSB, 2001).

While en route, the crew received an Aircraft Communication Addressing and Reporting System (ACARS) message from the flight's dispatcher that there was the possibility that adverse weather might impact their arrival, and suggested the crew expedite their arrival to beat approaching thunderstorms at the destination. In an after-accident interview, the first officer remarked that "there was no discussion of delaying or diverting the landing" (NTSB, 2001, p. 2) because of the thunderstorm activity approaching Little Rock National Airport.

The NTSB accident report describes the conversation between the captain and first officer and communications with Air Traffic Control when the flight reached the terminal area. The crew remarked several times about the intensity of the rain; the captain, who was the pilot flying, had difficulty maintaining sight of the runway environment and depended on the first officer to guide him to it. The controller issued several windshear advisories with winds gusting as high as 45 knots. The crew recognized that the current conditions at the airport exceeded the maximum crosswind limitation for a wet runway, yet they continued.

The NTSB accident report depicts a chaotic atmosphere in the cockpit of Flight 1420 with a fatigued crew that was rushing and knowingly operating in wind conditions exceeding allowable limits. This crew committed a plan continuation error by continuing the approach to Little Rock National Airport when the evidence was clear that they should not have attempted it. They chose a course of action that was incorrect for the given weather conditions. The crew believed that an accident would not happen; they believed they were invulnerable to the conditions.

Anti-Authority

Neff (2022) provides a deeper understanding of the hazardous attitude of anti-authority. The author explains that pilots exhibiting this hazardous attitude identify different kinds of authority, specifically, legitimate authority and illegitimate authority. Standard Operating Procedures (SOPs) and Federal Aviation Regulations (FARs) are examples of legitimate authority. These documents are written by a recognized authority. Illegitimate authority is perceived to come from a source that does not have delegated authority. Examples include an organization or an individual that does not have authority. Because of the delegated authority from the FAA or the airline, knowingly violating FARs or SOPs is a clear demonstration of an anti-authority, hazardous attitude.

On March 5th of 2000, a Southwest Airlines Boeing 737-300 overran the departure end of runway 08 at the Burbank-Glendale-Pasadena Airport in Burbank, California. Several factors combined to result in this accident. The accident flight departed for Burbank almost 2 hours late. The approach controller kept the flight higher than normal and requested the flight maintain 230 knots to control the sequencing of multiple flights to the airport. During the approach, the crew noted a 20 knot tailwind (NTSB, 2002).

During the approach, the captain worked to slow the aircraft. He deployed speed brakes, made the initial flaps extension, and extended the landing gear. He then quickly added flaps to 15. The captain called for flaps 30 and four seconds later flaps 40, stating “put [flaps] forty. [I]t won’t go, I know that. [I]t’s all right” (NTSB, 2002, p.3). At the time of this comment, the aircraft’s airspeed was 180 knots and climbed as high as 190 knots. His comment indicates that he knew he was exceeding an airspeed limitation for that flap position. The target speed for touchdown was calculated by the crew to be 138 knots. When the aircraft touched down, it was flying at a speed of 180 knots (NTSB, 2002).

The Southwest Airlines Flight Operations Manual (FOM) requires that crews use the Onboard Performance Computer (OPC) anytime certain conditions exist during operations. These conditions include operations with a tailwind and or to a short runway. Runway 08 at Burbank is 6,032 feet long, and as previously indicated, the crew recognized they were operating with a 20 knot tailwind during the approach. After the accident, the first officer admitted to the NTSB that he did not use the OPC, and the captain did not request that it be used (NTSB, 2002).

The Southwest Airlines FOM lists the requirements to be met and crew actions required during an approach. Callouts are required during normal approaches, and the manual requires additional callouts in the event of deviations from approach parameters. The pilot monitoring must make these callouts, and the pilot flying is required to acknowledge the callout and take immediate corrective action. The first officer acknowledged that he did not make the required callouts referencing excessive airspeed or sink rate deviations (NTSB, 2002).

Per Southwest’s FOM, the flight must meet certain criteria, and the approach must be stabilized by the point at which it enters the “slot”. The “slot” is identified as a point at 1,000 feet above ground level (AGL) where the aircraft speed and configuration must meet certain standards. The FOM requires that if these speed and configuration criteria are not met, the aircraft and crew are not prepared for a normal landing, and that a go-around procedure should be executed. When asked in a post-accident interview, the captain indicated that he recognized that he did not meet the criteria to be considered in the slot but could not explain why he did not execute the go-around (NTSB, 2002).

The crew’s failure to follow the requirements in the company FOM demonstrates their anti-authority, hazardous attitude. The company FOM represents a legitimate authority, yet the crew chose a course of action in direct violation of the requirements of the document. The crew continued the approach when clear evidence existed that they were not in a position to make a safe landing, committing a plan continuation error. Fortunately, no one was killed; however, several passengers and crew were injured (NTSB, 2002).

In all these examples, the aviation hazardous attitudes and plan continuation error are evident. An attitude impacts how we respond to an event; it is a predisposition that drives us toward a response (FAA, 2004; FAA, 2009; Nunez et al., 2019). In these examples, the pilot’s or crew’s hazardous attitudes acted as a predisposition that contributed to their decision to continue when clear evidence existed that an alternate plan was needed to avoid an accident or incident.

Recommendations

Aeronautical decision-making skills are trainable (Li et al., 2014). Decision-making is discussed at multiple points along a pilot's flight training journey. The topic is tested on FAA knowledge exams as part of that journey. It is incumbent on aviation educators at all levels to include realistic scenarios that require higher-order thinking skills to develop decision-making skills. Aviation educators must discuss hazardous attitudes and the impact they have on the decisions we make. All students should complete the Hazardous Attitude Assessment provided in AC60-22 (1991), understand how these attitudes impact the decisions we make, and have a strong grasp of the antidotes to the attitudes.

In aviation, we use mnemonics extensively. The DECIDE Model (Detect, Estimate, Choose, Identify, Do, Evaluate) is one such decision-making tool. Li et al. (2014) evaluated four decision-making mnemonic tools and determined the FORDEC model (Facts, Options, Risks & Benefits, Decisions, Execution, Check) to be the most effective in all decision-making scenarios. Pilot training should include the use of mnemonics, and the industry may consider moving from DECIDE to FORDEC.

Certified flight instructors, when conducting a flight review, should include scenarios specifically designed to evaluate a pilot's decision-making skills and should emphasize the danger of plan continuation. Commercial operators within their initial and recurrent training modules should include scenarios specifically designed to reinforce good decision-making skills. These scenarios should include an emphasis on the danger of continuing an operation when clear evidence exists that continuing is hazardous. Decision-making training, to include the five hazardous attitudes and operational pitfalls, must permeate all levels of flight training and operations.

Conclusions

Mosier et al. (2012) identified multiple factors impacting pilot decision making, including attention, automation heuristic/bias, expectation-driven processing, memory issues, operator state, team communication, monitoring/challenging, and resource management. According to the authors, these can all influence the situation assessment process and the initial steps taken in decision making. Advisory Circular 60-22 (FAA, 1991) addresses aeronautical decision making and outlines steps pilots must take to make good decisions. The first step the FAA lists is understanding one's hazardous attitudes.

Operational Pitfalls, as outlined in AC 60-22 (FAA, 1991), are "traps" that pilots can fall victim to; these are tendencies that can lead to poor decisions by pilots. Included in the list of operational pitfalls is what the FAA calls get-there-itis, which is another term for plan continuation bias. Plan continuation error, or bias, is an all-too-common occurrence among pilots. The NTSB (1994) found that nearly two-thirds of decision errors were classified as plan continuation. Plan continuation bias influences pilots to continue a flight or approach when conditions are such that it is not safe to do so.

The aviation Hazardous Attitudes can influence the decisions we make and how we make them. These attitudes can influence us to a point where we continue a planned flight even when conditions or circumstances clearly indicate that continuing is ill-advised at best or hazardous at worst. Plan continuation errors committed by flight crews have led to multiple aircraft accidents and incidents where the pilot or crew of the accident flight had ample information and time to recognize the conditions. While the hazardous attitude antidotes are the appropriate place to start, pilots must go beyond these to acknowledge that their hazardous attitudes may promote plan continuation error. A thorough risk assessment should be completed before any flight, and honest, realistic alternatives should be considered and planned.

Human beings make mistakes; we are fallible. It can be easy to look back at an event and critique the actions and decisions of others. This paper was not written to bring judgment on any pilots or flight crews, but rather to highlight a phenomenon that acts as a trap in some situations. As pilots, we need to first honestly identify the hazardous attitudes most prevalent within ourselves. Every flight should include some time for self-reflection about any hazardous attitudes and how they may manifest in the decision-making process. We need to complete a risk assessment with an eye to how our hazardous attitudes can influence any decisions that we may need to make. We must recognize that our hazardous attitudes may cause us to be more prone to plan continuation error and remain vigilant for that tendency to press on when conditions indicate we should re-evaluate the original plan and adjust (Orasanu et al., 2001). Aviation safety and our passengers' safety demand that we do this.

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