Enhancing Aviation Meteorology: Integrating Artificial Intelligence in Decision-Making of Air Traffic Controllers and Pilot Operations

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Abstract*: As Artificial Intelligence evolves and becomes more dominant, it can be integrated into different industries, such as meteorology, aviation, maritime, etc. In the field of aviation, weather is one of the factors that causes aircraft accidents and incidents. This study seeks to identify the significant relationship and differences in the perception of pilots and air traffic controllers in the integration of artificial intelligence in weather-related decision-making. This study is a combination of quantitative and qualitative research. Analyzing the challenges, reliability, and predictability of artificial intelligence in integrating it into weather forecasting and decision-making of pilots and ATCs could play a significant role in aviation safety. To further understand the perception of Pilots and Air Traffic Controllers in the integration of AI into forecasting and decision-making, the researchers gathered 19 respondents, consisting of 13 pilots and six air traffic controllers. The informants are three professionals from different departments in the field of aviation. Each one of them has the knowledge to answer interview questions and provide valuable insights in terms of the challenges, reliability, and predictability of artificial intelligence. In terms of the challenges of AI, multiple forecasting methods can improve reliability, which is beneficial for aviation purposes. In terms of AI reliability, the industry's recognition of machine learning's critical role in improving flight planning accuracy, AI significantly enhances forecasting capabilities; it is most effective when combined with human judgment and established methods. The findings underscore the importance of combining traditional techniques with modern AI in decision-making to tackle aviation weather challenges.

***Keywords*: Aviation, Artificial Intelligence, Pilot, Air Traffic Controller, Meteorology, decision-making, Weather.**

1. Introduction

In aviation, technological advancements evolve rapidly, from automated marshaling to autopilot systems, instrument landing systems, predictive maintenance, etcetera. As technologies become more complicated, human error becomes a more significant concern, and safety is the top priority. Artificial intelligence is a powerful concept that will change the ways of industrialization. Integrating artificial intelligence in meteorological forecasting could be crucial in optimizing flight operations. Artificial intelligence can improve the safety of flights by recommending alternative routes for pilots to fly when incoming weather is unfavorable.

Meteorology helps forecast how a flight operation will handle its journey time. After studying the weather forecast, Flight Operations Officers (FOO) can create an excellent route and altitude plan for pilots to fly on. If there is any severe weather, FOOs can search for routes that do not put the flight in danger. It relates to the cancellation of flights or rescheduling.

AI-driven systems serve a vital role in weather-predictive decision-making, aiding traffic controllers by providing them with real-time data analysis and forecasting capabilities. These systems are capable of processing wide varieties of meteorological data, identifying weather patterns, and even tracking potential hazards more quickly and much more accurately than traditional methods. AI assists air traffic controllers by providing precise predictions of weather conditions for flight paths, which reduces the risk of encountering hazards. Another advantage of using these systems would be to manage air traffic efficiently by minimizing flight delays and optimization of routes. Given these benefits, AI will become more significant in shaping the future of aviation operations.

Lin et al. (2023) stated that AI simplifies many tasks for us, but there's still uncertainty about the accuracy of its output compared to the work of professionals. As a result, it's important to acknowledge that AI may still produce errors or make incorrect assessments Zhao et al (2024). This paper explores the evolution of geoscientific inquiry, tracing the progression from traditional physics-based models to modern data-driven approaches facilitated by significant advancements in artificial intelligence (AI) and data collection techniques. Traditional models, which are grounded in physical and numerical frameworks, provide robust explanations by explicitly reconstructing underlying physical processes. However, their limitations in comprehensively capturing Earth's complexities and uncertainties pose challenges in optimization and real-world applicability. In contrast, contemporary data-driven models, particularly those utilizing machine learning (ML) and deep learning (DL), leverage extensive geoscience data to glean insights without requiring exhaustive theoretical knowledge. Moreover, Kumar, P. et al. (2022) Artificial intelligence is rapidly advancing and increasingly dominating the technological landscape. It can be applied in various domains, enabling tasks to be completed more quickly and reducing the time spent on activities. As AI continues to evolve, there is a concern that people may become more reliant on it.

Although technology ensures long-term competitiveness and sustainability in the aviation industry, significant challenges stem from human resources and their education. Sun et al. (2021) mentioned that technological and educational challenges towards pandemic-resilient aviation must be addressed to overcome these issues. An often-overlooked issue is the need for structured content analysis of current aviation curricula to evaluate their alignment with modern AI competency requirements. Kabashkin et al. (2023) highlighted the importance of preparing new professionals for new technologies in aviation, emphasizing the need for AI integration. Additionally, the research highlights a critical gap between advanced airlines, which have adopted cutting-edge technologies like machine learning and mixed reality, and those still relying on outdated strategies. Gultepe, I., et al. (2019) highlighted that the challenge in weather forecasting lies in the inability of any single system to provide fully accurate predictions; however, combining different methods can enhance reliability for aviation operations (Ghaffarian et al. 2023) Disasters can have devastating impacts on communities and economies, underscoring the urgent need for effective strategic disaster risk management (DRM). Although Artificial Intelligence (AI) holds the potential to enhance DRM through improved decision-making processes, its inherent complexity and "black box" nature have led to a growing demand for Explainable AI (XAI) techniques. These techniques facilitate the interpretation and understanding of decisions made by AI models, promoting transparency and trust. However, the current state of XAI applications in DRM, their achievements, and the challenges they face remain underexplored.

As per Ribeiro et al. (2020), Radars detected through signals make on-board sensors function. Without signals, the accuracy of these surveillance sensors, which indicate the aircraft's position, altitude, identity, and other parameters, may be disrupted. Although unmanned aviation promotes advancement, malfunctions may affect the aircraft's ability to detect obstacles and maintain a safe flight path, causing head-on collisions and catastrophes. Based on Albahri et al. (2024), Artificial intelligence (AI) holds significant promise for advancing natural disaster management through the use of predictive models that analyze extensive datasets, identify patterns, and forecast potential disasters. These models facilitate proactive measures such as early warning systems (EWSs), evacuation planning, and resource allocation, addressing the substantial challenges associated with natural disasters. Based on Snezhanaszillat (2024), the preciseness of weather prediction has been considerably improved by artificial intelligence through the processing of large datasets. To avoid errors, there are a few issues that must be resolved, such as ensuring that the incoming data is of a high enough quality. AI systems can be expensive and difficult to access due to their high computational requirements. Moreover, continual model improvement is necessary to adapt to changing climate trends and guarantee that AI-driven forecasts continue to be reliable and helpful.

According to McGovern et al. (2024), forecasting weather is important because it helps farmers take the necessary precautions to safeguard their crops, especially when it comes to rainfall. The use of machine learning (ML) algorithms and other sophisticated technologies for rainfall prediction is discussed in the article. Because of their complex computing methodologies, machine learning approaches are emphasized for their capacity to produce precise forecasts. Traditional rainfall forecasting, which makes predictions about future patterns based on past data, is another technique that was mentioned. Machine learning (ML) is ideally suited for contemporary uses, making use of cutting-edge tools and algorithms to improve prediction precision. The benefits of artificial intelligence (AI) in weather prediction are further examined by Kumar et al. (2023), who emphasize AI's ability to provide useful data for decision-making. The piece highlights the transition from conventional techniques to cutting-edge AI methods, such as deep learning, which has become more well-known for its capacity to handle complex data. Incorporating AI methods, especially neural networks, has proven essential to improving weather forecasting. The advancements in handling temporal and spatial data dependencies, made possible by advances in hardware and neural network training with large parameter sets, are also highlighted in the research. These studies highlight how AI and ML are revolutionizing weather forecasting and have wider implications for environmental and agricultural planning.

Data is not easy to get, especially when we are talking about unpredicted subjects like weather. Based on the study of Schultz et al. (2021), the Earth is constantly changing. A lot of factors that affect the state of the environment are arising, one good example of this would be climate change. Thus, unable to obtain accurate information about the weather in certain regions of the world. In comparison to this, Mamalakis et al. (2022) emphasized that it is possible to acquire a more accurate forecast of precipitation and a larger and higher quantity of satellite imagery through the use of Explainable AI or XAI, which could be beneficial in the future for weather forecasting and creating preventive measures for violent or unfavorable weather. Another way of utilizing AI for the prediction of weather is through the use of Big Data. It was observed from the study of Fu et al. (2023) that Big Data is a collection of various types of data that is growing continuously and plays an important role in monitoring air quality. Environmental monitoring and algorithms are utilized to collect, quickly process, and analyze the environmental data. This data collected can be used to predict the future trend of air quality.

AI2ES research in explainable AI is to establish trust in professionals in their field of work. McGovern et al. (2022) mentioned that it is focused on environmental science applications such as developing trustworthy AI methods for weather, climate, and coastal hazards. This also integrates laws of physics and realistic interpretations which can influence users' key decision-making and improve the reliability of AI in work settings. Murugan et al (2022) referred to Artificial Intelligence as a boon in many fields. Their study is about utilizing machine learning in analyzing weather conditions which can be integrated into cameras. The system also has image classification techniques that can help weather forecasters assess real-time data and not only rely on meteorological data. Hybrid forecasting is the combination of dynamical models (mathematical representations of atmosphere behavior) and data-driven models (machine learning / Artificial Intelligence) which enhances weather prediction capabilities. Slater et al. (2023) study on hybrid forecasting mentioned a broad variety of dynamical physics-based models such as numerical weather prediction, climate, land, hydrology, and earth system models which when integrated into statistical or machine learning methods, can harness the strengths of AI and increase prediction capability.

Artificial intelligence and numerical weather prediction systems are used to overcome limitations associated with conventional NWP models. Lukacz, P.M. (2024) pointed out that the NWP system can be significantly enhanced by improving data assimilation, model optimization, and postprocessing outputs through AI technology output improvements. Moreover, Pik E. et al. (n.d) stated in the research that integrating Dependent Surveillance-Broadcast version 3 with Artificial Intelligence could predict weather and help optimize flight operations. The technology turns the GA aircraft into mobile weather stations, providing weather information even in places inaccessible by roads and ground-based observation sites. This technology will improve weather predictions for Air Traffic Controllers (ATC) and Pilots to enhance its dependability. In addition, Ziakkas et al. (2024) stated that the operations of the National Weather Service have implemented the integration of Artificial Intelligence to enhance the precision and effectiveness of weather forecasting. It has been reported that weather forecast accuracy improved by 10%; the Federal Aviation Administration (FAA) also utilizes AI to forecast and detect actual time weather.

The aviation industry is evolving at a fast pace. Artificial intelligence's innovation and integration into aviation systems improve flight operations and decision-making. AI-driven predictive models enhance operational efficiency by predicting possible flight obstructions and delays. In meteorology, AI gives opportunities for improvements by offering real-time data analysis and forecasting approaches to air traffic controllers and pilots. This helps them make educated choices regarding flight routes, decreases the chances of encountering extreme weather, and enhances overall air traffic management. With the progression of AI, its significance to weather prediction and decision-making will increase, Shaping the future of aviation.

A. Background of the Study

Weather is one of the most crucial parts that play a significant role in an aircraft's safety and efficiency, most notably in the aviation industry. It is predictable, yet there is still a need to increase the improvement of having a quick source that enables information that disseminates the usual method, which needs a certain amount of time to have the best solution to comply with the problem.

The rapid increase of artificial intelligence not only in the use of modern works but also in technical works makes us curious about how and where artificial intelligence can bring us in the future. With the help of AI, it increases and improves the capacity to accomplish tasks on time. It also gives us quick answers that lessen the time of identifying and understanding a specific concern or problem.

Despite numerous research efforts in applying AI to Air Traffic Management (ATM), it has yet to become fully operational or deliver noticeable benefits to end users. The slow progress in integrating AI into the ATM domain can be attributed to its critical nature, where human lives are at stake, making safety the top priority. Historically, safety in ATMs has been ensured through human-in-the-loop systems, particularly with Air Traffic Controllers (ATCOs). As the field evolves, experts argue that future systems will likely remain human-centered.

Meteorological data is particularly challenging in air traffic management due to its complex, dynamic, and unpredictable nature. In the past, traditional weather forecasting models, though accurate to an extent, could only sometimes provide real-time adaptive solutions to immediate challenges air traffic controllers face. This gap has driven the interest in AI-based solutions, particularly those that leverage machine learning to analyze vast datasets and provide predictive insights into weather patterns and their potential impacts on flight operations.

In recent years, the role of machine learning in meteorology, particularly in operational meteorology for weather forecasting, has seen significant growth. Historically, the field has relied on traditional methods, but advancements in machine learning have increasingly contributed to more accurate and efficient predictions. However, despite this progress, much of the research surrounding climate change, a critical issue in Earth sciences, has yet to embrace machine learning techniques fully. While there are numerous studies on global, regional, and local climate change impacts, many of these works still do not integrate machine learning approaches, highlighting the potential for further exploration and application in the future.

B. Theoretical Framework

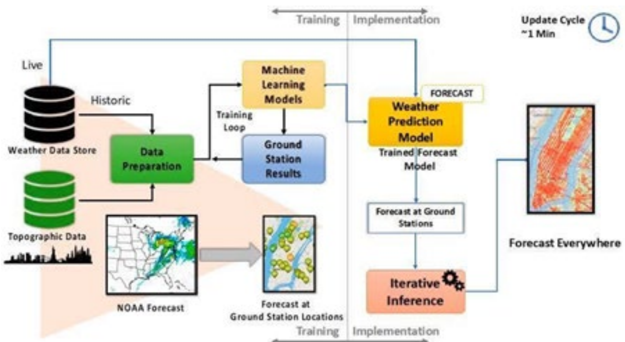

Fig. 1. General urban area microclimate prediction (gump) tool diagram

This study is anchored on the General Urban Area Microclimate Prediction tool by Adkins, K.A. et al. (2023). Figure 1 illustrates the use of data frozen by local weather sensors and computational fluid dynamics integrated with the prediction capability of machine learning. It starts with a collection of live meteorological and topographic data, which can now be referred to as past data, which the machine learning model will use to analyze. The derived analyses will be used to train the model repeatedly until the model can provide a reliable prediction. The trained forecast model will be equipped with an iterative inference scheme that progressively improves prediction capability especially on information lacking locations. The prediction tool is displayed on a live interface which provides wind field vectors within the area of the flight plan. This prevents an interruption and risk to an operation.

This study aims to advance the decision-making process of air traffic controllers and pilots in relevance to unforeseen weather, GUMP will play a significant role in shaping an upgraded version of this system; such as expanding its range capabilities. The theory also considered real-time decision-making by emphasizing the monitoring of dynamic flight environments. It enhances the ATC and Pilots' weather awareness by identifying weather variations and alerting them to potential hazards. Moreover, safety and efficiency will be enhanced; GUMP can help prevent accidents and incidents and minimize the margin of disasters caused by weather events.

C. Conceptual Framework

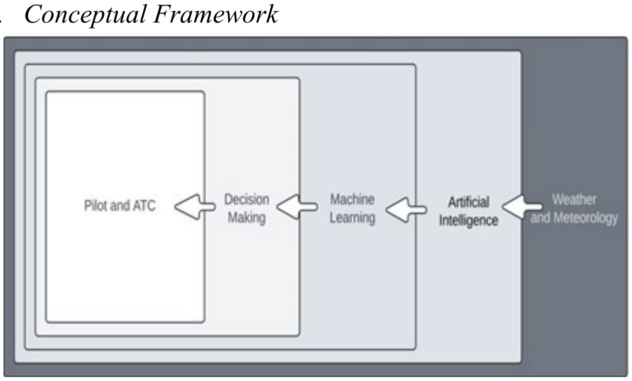

Fig. 2. Artificial intelligence integrated weather forecasting for atc and pilots

The conceptual framework (figure. 2) depicts the interconnected processes involved between Pilots and ATC in decision-making. The weather and meteorology serve as the basis of the whole process, as it is the source of raw data to be used by the subsequent processes. Artificial intelligence comes into play by using machine learning as a tool to analyze the raw data from the observed weather by continuous teaching of the AI model. The algorithm formed from the analyzed raw data and repeated inputs of data will make the AI model ready to be used for weather-related decision-making. The interpretation of data formed by the machine learning model will provide options for decision-making which will ultimately fall at the responsibility of the pilots and ATC. This study is guided by Adkins, K.A. et al. model which is a specialized weather forecasting system for urban and local areas. The system uses the capability of machine learning as a tool for temporal predictions.

D. Statement of the Problem

This study sought to assess the advantages of implementing AI-driven predictive systems for enhancing weather-related decision-making processes. Specifically, the study sought the answers to the following questions:

1. What are the challenges of utilizing Artificial Intelligence for analyzing meteorological data for weather-related decisions?
2. How reliable is A.I in producing accurate meteorological data despite its limitations which can affect flight operation procedures?
3. How can AI depict unpredictable weather patterns at a certain aerodrome?
4. Is there a significant difference in the perceptions of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making?
5. Is there a significant relationship between the perceptions of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making?
6. Based on the gathered data from the respondents, why are there significant relationships and significant differences between the perception of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making?

E. Hypothesis

There is no significant difference in the perceptions of air traffic controllers and pilots regarding the integration of AI-driven weather forecasting for decision-making.

There is no significant relationship between the perceptions of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making.

F. Significance of the Study

This research study explored the potential of integrating Artificial Intelligence (AI) into Weather Meteorology to enhance safety and efficiency in flight operations. By examining the impact of AI-driven weather forecasting analysis, this research aimed to contribute to the following areas:

1. *Air Traffic Controllers* - The findings of this study will benefit air traffic controllers because Artificial Intelligence integrated forecasting analysis models can help narrow options in flight operations. The output can help with ATC visualizations which can help improve decision-making and enhance safety. This system can help air traffic controllers manage the airspace effectively and efficiently and may significantly avoid weather-related accidents.
2. *Pilots* - Pilots are the people who execute every decision for the entire flight duration. The purpose of this study is to help pilots in having compressed information about the safest routes available should there be difficulty in finding safe routes. Enhancing aviation meteorology through the utilization of AI will also improve the decision-making process of pilots when in operations.
3. *Airline Companies* - The output of this study will also be most beneficial to airline companies because it will help improve their overall performance and management capabilities. The enhanced forecasting model provides accurate weather predictions so that airlines can optimize their route and flight plans, operational efficiency, and enhance customer experience. An accurate forecast will help airline companies to prepare for short-term and possibly long-term weather thus promoting safety.
4. *Flight Operations Officer* - Flight operations officers are the people who organize the essential documents for the flight before it takes place, planning the flight route also falls under the FOO's responsibility. This study will help FOOs in carefully planning out the routes in which adverse weather conditions might affect the flight path they are handling. FOOs can also be alerted in a much earlier time if there would be potential flight delays and could take the appropriate actions to minimize delays.
5. *Future Researchers* - This research study will be a helpful guide for further Aviation-based studies, especially Weather Meteorology. The findings of this study will provide insights for future researchers on integrating Artificial Intelligence in Weather Meteorology for aviation purposes, such as human-AI collaboration, AI algorithms, Weather forecasting, etcetera. This research will be the stepping stone for new experiments and development in aviation.

2. Methodology

A. Research Design

The researchers selected a mixed method, also known as a combination method. It comprises quantitative and qualitative methods, conducting their research with the desired target population possible. In the quantitative aspect, it has a correlational approach that delves into the relationship between the variables. On the other hand, cross-tabulation analysis is to analyze the data used and gathered for the research to examine the objectives needed for the study. A qualitative approach called the narrative method focuses on interpreting the construction of a story and narrative from a respondent. Lastly, thematic analysis is a qualitative method of analyzing data from interviews and transcripts. This involves organizing and carefully interpreting data to identify an underlying meaning.

The researchers opted for a narrative method, employing in-depth interviews to document experts' detailed and individual experiences applying artificial intelligence meteorology. This approach provided rich, descriptive insights that would not have been attainable with only numerical data, making it perfect for examining complex problems and comprehending people's subjective viewpoints. By listening to these stories, the researchers aimed to gain a deeper understanding of AI's real-world implications and limitations in weather-related decision-making. In contrast, the correlational approach used questionnaires and surveys to gather data from more significant participants. This method allowed the researchers to statistically analyze the relationships between variables, such as the differing perceptions of AI among air traffic controllers and pilots or the effectiveness of AI systems based on user training. The choice of this method was driven by its ability to measure and quantify patterns, enabling the researchers to understand the connections between crucial factors without manipulating any variables.

B. Respondents

The target respondents of this research consist of student pilots who have at least completed their first solo flight training, private licensed pilots, commercial licensed pilots, rotorcraft pilots, glider pilots, and Air Traffic Controllers (tower, approach, area). While Slovin’s formula wasn’t used, a sample size of 30 respondents was determined based on the specialized nature of the topic and the availability of qualified participants.

The researchers conducted an external survey with a sample size of 30. They received 19 responses, resulting in a response rate of 63.33%. To compute the response rate, the researchers divided the responses by the sample size and multiplied by 100. The acceptable response rate for an external survey is 10% to 15%. Therefore, the results were way beyond the acceptable rate.

Table 1
Frequency and percent distribution of the age bracket of the respondents

Age	Frequency	Percentage
16-21	3	15.80
22-30	11	57.90
31-39	2	10.50
40 above	3	15.80
Total	19	100.00

The researchers sought to know the frequency and percent distribution of the age of the respondents. The age brackets set by the researchers are: 16-21, 22-30, 31-39, and 40 and above. Since this is a special case of research, the total number of respondents is 19. Among the respondents, ages 22-30 have the greatest number of respondents which comprises pilots, ATC, and student pilots. While the least number of respondents are at the ages of 31-39.

Table 2
Frequency and percent distribution of the gender bracket of the respondents

Gender	Frequency	Percentage
Male	13	68.40
Female	6	31.60
Total	19	100.00

Table 2 shows the frequency and percentage distribution of the gender bracket of the respondents. From the total of 19 respondents, 13 were male, while 6 of them were female. In terms of percentage, 13 of the male respondents is equivalent to 68.40% and 6 of the female respondents converts to 31.60% of the total respondents.

Table 3
Frequency and percent distribution of the profession bracket of the respondents

Age	Frequency	Percentage
Pilot	13	68.40
Air Traffic Controller	6	31.60
Total	19	100.00

Table 3 summarizes the respondent's profession frequency and percentage distribution. To further understand the relationship and difference of the perception of Air Traffic Controllers and Pilots on the integration of AI to forecasting and decision-making, the researchers found 13 pilots and 6 Air Traffic Controllers as respondents for the research

The informants are three professionals who came from different departments in the field of aviation, each one of them has the knowledge to answer interview questions and provide valuable insights in terms of the challenges, reliability, and predictability of artificial intelligence. These three informants were selected based on their knowledge and experience. One of which is a flight dispatcher who validated the survey questionnaire, another is an Air Traffic Controller, a respondent from the final survey, and the third is a commercial pilot with extensive flying experience.

C. Settings

The study was conducted at an aviation school located at Lombos Street, San Isidro Paranaque, Metro Manila, Philippines.

This study is focused on determining whether artificial intelligence can aid pilots and air traffic controllers narrow down the potential safe routes for pilots to fly in severe weather conditions. The respondents must be pilots, air traffic controllers, and flight operations officers to understand better the scenarios the researchers are studying.

The study is focused on respondents who are student pilots who have at least completed their first solo flight, private licensed pilots, commercial licensed pilots, rotorcraft pilots, and glider pilots. For air traffic controllers, the study will only be limited to tower controllers, approach controllers, and area controllers. And lastly, Flight operations officers. Any other certified pilots and air traffic controllers beyond the stated ratings shall be considered outside the scope of this study.

This academic paper is packed with factual information from the researchers and was derived from other research that formulated this study. The review of related literature of this study also indicates that it is new and has significant room for research and development. Lastly, the contents of this study are original and backed with facts from the review of related literature.

D. Instrumentation

The researchers tailor the survey questionnaire for this study to gather reliable and relevant data. The questionnaire was validated by three individuals with relevant expertise in the field of aviation.

An Air Transportation Department instructor, provided valuable feedback on the questionnaire's clarity, relevance, and comprehensiveness. He suggested minor revisions to certain questions to enhance their clarity and applicability. An Aeronautical Engineering Department offered insights into the technical accuracy and relevance of the questions. He recommended removing or revising a few items to ensure their alignment with the study's focus. An aircraft mechanic from Singapore Aero Engine Services Private Limited (SAESL) shared his insights on using or having artificial intelligence in the aviation field, which is the focus of their research. He recommended revising and removing a particular question from the questionnaire and replacing it with a more detailed question that deals with the research topic.

The pilot testing for AI predictive systems in aviation meteorology was conducted on October 7, 2024, at an aeronautical school located in Parañaque City. The survey was administered via Google Forms and was open to all technical courses, including BS Air Transportation, BS Aviation Maintenance Technology, BS Avionics Technology, BS Aeronautical Engineering, and BS Industrial Engineering. All responses will remain confidential and ensured to not be collected which could compromise their privacy. Of the 43 samples analyzed, 88.4% were from 4th-year students, 9.3% from 3rd-year students, and 2.3% from 1st-year students. Most respondents, 90.7%, were enrolled in BS Air Transportation, while 9.3% were pursuing BS Aviation Maintenance Technology.

The researchers conducted the final survey after the pilot testing. Consent, in accordance with the Privacy Act of 2012 was first asked. The respondents are willing to participate and have given consent for the processing, releasing, and/or retention of personal information. Demographics is also part of the information sought by the researchers. The majority of the respondents are from ages 22-30, followed by ages 16-21, ages 40 and bove, and ages 31-39. The genders of the respondents are male (68.40%) and female (31.60%). The respondents were also asked about their ratings in the field. The majority are student pilots (38.10%), commercial pilots (14.30%), and private pilots (9.50%). Air Traffic Controllers also played a part in the survey, tower controllers (14.30%), approach controllers (9.50%), and area controllers (9.50%).

The researchers identified the most pressing issues based on the research statements and developed eight questions to interview three participants. These questions will explore significant differences in the perceptions of air traffic controllers and pilots regarding the challenges, reliability, and predictability of AI in weather forecasting.

E. Data Analysis

For respondents' profiles and weighted mean, the researchers used frequency and percentage. The researchers used Pearson correlation (r) to analyze the significant relationship between the perceptions of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making.

On the other hand, to examine the significant difference between the perceptions of ATC and Pilots on integrating AI-driven weather forecasting for decision-making, the researchers used a T-test. The researchers used thematic analysis for interviewing some of the participants which can give valuable insights to the research.

F. Ethical Considerations

The researchers are dedicated to protecting the privacy of personal data by using robust access restrictions and encryption. Participant health and safety are considered the top priorities by carrying out in-depth risk assessments and putting procedures in place to deal with any data problems. Furthermore, the researchers are committed to utilizing cutting-edge security methods and frequent audits, the data storage solutions being used are extremely safe and impenetrable to hackers.

Before starting the study, the researchers shall get the institution or firm to grant the required licenses and authorization. To guarantee compliance and oversight, a representative from the organization or business firm shall go along with the researchers while they conduct the study. Every site safety protocol is guaranteed to adhere to the school requirements.

In conducting the survey, the respondents' participation is ensured voluntarily while sharing their knowledge and insights. While the survey is ongoing, there will be no undue pressure that would be felt by the participants, thus, reinforcing the ethical integrity of the study. Should there be a circumstance where a participant decides to end the session, the researchers will oblige. Furthermore, the study will not generate any negative consequences or disruptions for the respondents as it will be carried out at a time most convenient to them.

In the event of unforeseen interruptions, online surveys will be considered as an alternative method to collect data, ensuring the continuity of the study. Adequate time will be allocated to the respondents to minimize scheduling conflicts and enhance their comfort during participation. Additionally, the safety of the survey location will be thoroughly assessed, and the safety and well-being of all participants will remain the top priority throughout the process.

3. Result and Analysis

A. The Challenges of Utilizing Artificial Intelligence for Analyzing Meteorological Data for Weather-Related Decisions

Table 4
Challenges of utilizing artificial Intelligence for analyzing meteorological data for weather-related decisions

Challenges of AI	Mean	Standard Deviation	Interpretation
Artificial Intelligence (AI) is accurate and efficient for daily tasks.	3.00	0.58	Agree
Traditional models are more reliable than AI models.	3.05	0.71	Agree
Artificial intelligence is becoming an increasingly dominant force in technology, capable of streamlining tasks across various domains, such as weather prediction	3.32	0.58	Agree
The challenges of limited labeled data affect the effectiveness of AI in enhancing aviation safety.	3.42	0.61	Agree
Combining different forecasting methods is necessary to improve the accuracy of weather predictions for aviation operations.	3.79	0.42	Strongly Agree
There are potential benefits of Explainable AI in disaster risk management sufficiently understood and implemented to ensure effective and transparent decision-making.	3.47	0.51	Agree
It is possible for the aviation field, in this state of technology specifically for weather prediction process and decision making, to operate unmanned through the use of Artificial intelligence.	2.63	1.01	Agree
There are possible obstacles that may affect the accuracy of AI-driven weather prediction systems	3.63	0.5	Strongly Agree
AI improves resource management during weather related disaster	3.32	0.48	Agree
Composite Mean	3.29	0.27	Agree

Legend: 3.51 - 4.00 Strongly agree; 2.51 - 3.50 Agree; 1.51 - 2.50 Disagree; 1.00 - 1.50 Strongly disagree

The table above indicated the challenges associated with utilizing artificial intelligence (AI) for meteorological data analysis in weather-related decision-making resulting in a composite mean of 3.29, indicating a general agreement among respondents on the statements presented. The listed challenges highlight various obstacles that may be encountered as AI continues to advance within this field. In particular, Statement No. 5, "Combining different forecasting methods is necessary to improve the accuracy of weather predictions for aviation operations," received the highest mean score of 3.79, based on collected data. This response underscores a strong recognition from professionals in the aviation industry of the critical role that multifaceted forecasting methods play in enhancing weather prediction accuracy, especially given the technical limitations AI advancements might impose on professional expertise. The significance of Statement No. 5 among the other responses reinforces the importance of multi-method approaches to enhance meteorological precision without AI dominance. Overall, survey results suggest a general agreement on the challenges of applying AI in meteorological data analysis for weather-related decision-making. Gultepe et al. (2019), weather forecasting faces significant challenges due to the limitations of individual systems in achieving complete accuracy. However, integrating multiple forecasting methods can improve reliability, which is especially beneficial for aviation operations.

B. Artificial Intelligence is Reliable in Producing Accurate Meteorological Data Despite its Limitations which can Affect Flight Operations Procedures

Table 5
Artificial intelligence reliability in producing meteorological data

Reliability of AI	Mean	Standard Deviation	Interpretation
Machine learning advancements in weather prediction are essential for improving the accuracy of flight planning and safety in the context of changing climate conditions	3.53	0.51	Strongly Agree
Advancements in artificial intelligence methods, such as deep learning, have notably improved the accuracy and reliability of weather predictions.	3.26	0.45	Agree
Climate change forecast for the next 10 years useful in determining future pilot plans	3.11	0.81	Agree
The use of explainable artificial intelligence enough to provide an accurate forecast of prediction	3.05	0.62	Agree
Air quality is a factor that determines future weather patterns	3.47	0.51	Agree
Composite Mean	3.28	0.35	Agree

Legend: 3.51 - 4.00 Strongly agree; 2.51 - 3.50 Agree; 1.51 - 2.50 Disagree; 1.00 - 1.50 Strongly disagree

The table above reveals that professionals generally agree on the reliability of Artificial Intelligence (AI) in meteorological data analysis for aviation, with a composite mean of 3.28. Notably, the highest-rated statement scored 3.53, highlighting the industry's recognition of machine learning's critical role in improving flight planning accuracy. This response underscores the aviation industry's recognition of machine learning's vital role in enhancing prediction accuracy, particularly in the context of complex weather patterns. The findings also reflect strong support for integrating AI with human expertise, which is crucial for enhancing weather prediction accuracy. This consensus underscores the importance of adopting a multifaceted approach to maintain reliable forecasts. To tackle the challenges identified, it would be beneficial for aviation organizations to invest in training programs that blend AI technologies with professional insights, ultimately improving decision-making processes. Research supports this view, indicating that while AI significantly enhances forecasting capabilities, it is most effective when combined with human judgment and traditional methods Kumar et al. (2023).

C. AI depict Unpredictable Weather Patterns at a Certain Aerodrome

The table reveals that professionals generally agree on the reliability of Artificial Intelligence (AI) in unpredictable weather patterns in aviation, with a composite mean of 3.21. Notably, the highest-rated statement scored 3.58, indicating strong agreement that the combination of AI and dynamical models enhances weather prediction capabilities. This finding underscores the industry's recognition of machine learning's critical role in improving the accuracy of weather forecasts, especially in the context of complex weather patterns. While professionals acknowledge AI's potential, they also identify challenges that can hinder predictive capabilities and raise concerns about data quality and privacy.

Table 6
A.I depict unpredictable weather patterns at a certain aerodrome

Predictability of AI	Mean	Standard Deviation	Interpretation
Artificial intelligence trustworthy enough for professionals to use and rely on especially in weather prediction	2.63	0.76	Agree
There are challenges in the integration of machine learning into cameras that can hinder weather predictive capabilities.	3.11	0.46	Agree
The combination of AI and dynamical models (Mathematical weather data) enhances weather prediction capabilities.	3.58	0.51	Strongly Agree
Integrating AI technology can enhance and improve Numerical Weather Prediction (NWP) systems by improving data assimilation, model optimization, and post processing outputs.	3.37	0.5	Agree
There are potential challenges or limitations to integrating Dependent Surveillance-Broadcast version 3 with Artificial Intelligence for weather data collection, such as data quality, privacy concerns, or technical difficulties.	3.21	0.42	Agree
The integration of AI into the National Weather Service's operations could improve the accuracy and reliability of meteorological forecasts.	3.37	0.6	Agree
Composite Mean	3.21	0.34	Agree

Legend: 3.51 - 4.00 Strongly agree; 2.51 - 3.50 Agree; 1.51 - 2.50 Disagree; 1.00 - 1.50 Strongly disagree

Nevertheless, there is a consensus on the benefits of integrating AI technologies to enhance meteorological forecasting. This supports the notion that a comprehensive approach, combining AI with human expertise, is essential for reliable meteorological forecasts. To tackle the identified challenges, aviation organizations are recommended to invest in training programs that blend AI technologies with professional insights, ultimately improving decision-making processes. Research by McGovern et al. (2019) supports this perspective, indicating that while AI significantly enhances forecasting capabilities, it is most effective when combined with human judgment and established methods.

D. Significant Difference from the Perceptions of Air Traffic Controllers and Pilots on Integrating AI Driven Weather Forecasting for Decision-Making

Table 7
T-test result for significant difference from the perception of air traffic controllers and pilots regarding the challenges of utilizing artificial intelligence for analyzing meteorological data for weather-related decisions

Statements	Profession	Mean	Standard Deviation
Artificial Intelligence (AI) is accurate and efficient for daily tasks.	Pilot	2.92	0.64
	Air Traffic Controller	3.17	0.41
Traditional models are more reliable than AI models.	Pilot	3.31	0.63
	Air Traffic Controller	2.5	0.55
Artificial Intelligence is becoming an increasingly dominant force in technology, capable of streamlining tasks across various domains, such as weather prediction	Pilot	3.38	0.65
	Air Traffic Controller	3.17	0.41
The challenges of limited labeled data affect the effectiveness of AI in enhancing aviation safety.	Pilot	3.38	0.65
	Air Traffic Controller	3.5	0.55
Combining different forecasting methods is necessary to improve the accuracy of weather predictions for aviation operations.	Pilot	3.85	0.38
	Air Traffic Controller	3.67	0.52
There are potential benefits of Explainable AI in disaster risk management sufficiently understood and implemented to ensure effective and transparent decision-making.	Pilot	3.54	0.52
	Air Traffic Controller	3.33	0.52
It is possible for the aviation field, in this state of technology specifically prediction process and decision making to operate unmanned through the use of Artificial Intelligence	Pilot	2.54	1.05
	Air Traffic Controller	2.83	0.98
There are possible obstacles that may affect the accuracy of AI-driven weather prediction systems	Pilot	3.77	0.44
	Air Traffic Controller	3.33	0.52
AI improves resource management during weather related disaster	Pilot	3.38	0.51
	Air Traffic Controller	3.17	0.41

Table 8
Significant difference in the perception of air traffic controllers and pilots regarding the challenges of utilizing artificial intelligence for analyzing weather-related decisions

Statements	Sig.	Decision
Artificial Intelligence (AI) is accurate and efficient for daily tasks.	0.479	ACCEPT
Traditional models are more reliable than AI models.	0.797	ACCEPT
Artificial intelligence is becoming an increasingly dominant force in technology, capable of streamlining tasks across various domains, such as weather prediction	0.045**	REJECT
The challenges of limited labeled data affect the effectiveness of AI in enhancing aviation safety.	0.553	ACCEPT
Combining different forecasting methods is necessary to improve the accuracy of weather predictions for aviation operations.	0.135	ACCEPT
There are potential benefits of Explainable AI in disaster risk management sufficiently understood and implemented to ensure effective and transparent decision-making.	0.298	ACCEPT
It is possible for the aviation field, in this state of technology specifically for weather prediction process and decision making, to operate unmanned through the use of Artificial intelligence.	0.835	ACCEPT
There are possible obstacles that may affect the accuracy of AI-driven weather prediction systems	0.42	ACCEPT
AI improves resource management during weather related disaster	0.039**	REJECT

Legend: * with significant difference: ** with very significant difference

The table summarized the significant difference in the perceptions of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making in Statement of the Problem number 1. The majority of the respondents showed that there is no significant difference in the perceptions for Statement of the Problem number 1 with values of 0.479, 0.797, 0.553, 0.135, 0.298, 0.835, and 0.420 respectively. However, some showed very significant differences in questions 3 and 9 with values of 0.045 and 0.039 respectively. This implies that the perceptions of both professions in the use and purpose of AI differ significantly. This is observed in the research conducted by McGovern et al (2019) in explainable AI which focuses on establishing trust in AI for professionals which is not deemed as reliable in the field.

Table 9
T-test results for significant difference from the perceptions of air traffic controllers and pilots regarding the reliability of AI in producing accurate meteorological data

Statement	Profession	Mean	Standard Deviation
Machine learning advancements in weather prediction are essential for improving the accuracy of flight planning and safety in the context of changing climate conditions	Pilot	3.62	0.51
	Air Traffic Controller	3.33	0.52
Advancements in artificial intelligence methods, such as deep learning, have notably improved the accuracy and reliability of weather predictions.	Pilot	3.31	0.48
	Air Traffic Controller	3.17	0.41
Climate change forecast for the next 10 years useful in determining future pilot plans	Pilot	3.23	0.73
	Air Traffic Controller	2.83	0.98
The use of explainable artificial intelligence enough to provide an accurate forecast of prediction	Pilot	3.08	0.64
	Air Traffic Controller	3	0.63
Air quality is a factor that determines future weather patterns	Pilot	3.62	0.51
	Air Traffic Controller	3.17	0.41

The table summarizes the significant difference in the perceptions of air traffic controllers and pilots on integrating AI-driven weather forecasting decisions in Statement of the Problem number 2.

Table 10
Significant difference in the perception of air traffic controllers and pilots regarding the reliability of ai in producing accurate meteorological data

Statements	Sig.	Decision
Machine learning advancements in weather prediction are essential for improving the accuracy of flight planning and safety in the context of changing climate conditions	0.671	ACCEPT
Advancements in artificial intelligence methods, such as deep learning, have notably improved the accuracy and reliability of weather predictions.	0.179	ACCEPT
Climate change forecast for the next 10 years useful in determining future pilot plans	0.939	ACCEPT
The use of explainable artificial intelligence enough to provide an accurate forecast of prediction	0.7	ACCEPT
Air quality is a factor that determines future weather patterns	0.039**	REJECT

Legend: * with significant difference: **with very significant difference

According to the data, the majority shows that there is no significant difference between the perceptions of air traffic controllers and pilots in questions 10 to 14 with values of 0.671, 0.179, 0.939, and 0.700. However, a question about the air quality shows that there is a significant difference with a value of 0.039. This implies that the perceptions of both professions differ in using air quality as a factor for weather prediction. This is evident in the research conducted by Fu, Li & Chen, (2023) which integrates air quality for monitoring weather using artificial intelligence.

The table above shows the significant difference between the perceptions of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making in Statement of the Problem number 4. Based on the data presented above there are three questions that have no significant difference between the perceptions of air traffic controllers and pilots for questions 16, 17, and 19 with question 16 having a value of 0.973, question 17 with 0.839, and question 19 with a value of 0.135. Other questions such as questions 18 and 20 signify a significant difference, with question 18 having a very significant difference with a value of 0.009, while question 20 has a value of 0.036.

Table 11
T-test result of significant difference from the perceptions of air traffic controllers and pilots on how AI depicts unpredictable weather patterns at a certain aerodrome

Statement	Profession	Mean	Standard Deviation
Artificial intelligence trustworthy enough for professionals to use and rely on especially in weather prediction	Pilot	2.62	0.77
	Air Traffic Controller	2.67	0.82
There are challenges in the integration of machine learning into cameras that can hinder weather predictive capabilities.	Pilot	3.08	0.49
	Air Traffic Controller	3.17	0.41
The combination of AI and dynamical models (Mathematical weather data) enhances weather prediction capabilities.	Pilot	3.69	0.48
	Air Traffic Controller	3.33	0.52
Integrating AI technology can enhance and improve Numerical Weather Prediction (NWP) systems by improving data assimilation, model optimization, and post processing outputs.	Pilot	3.46	0.52
	Air Traffic Controller	3.17	0.41
There are potential challenges or limitations to integrating Dependent Surveillance-Broadcast version 3 with Artificial Intelligence for weather data collection, such as data quality, privacy concerns, or technical difficulties.	Pilot	3.15	0.38
	Air Traffic Controller	3.33	0.52
The integration of AI into the National Weather Service's operations could improve the accuracy and reliability of meteorological forecasts.	Pilot	3.46	0.66
	Air Traffic Controller	3.17	0.41

Table 12
Significant difference in the perception of air traffic controllers and pilots on how AI depicts unpredictable weather patterns at a certain aerodrome

Statements	Sig.	Decision
Artificial intelligence trustworthy enough for professionals to use and rely on especially in weather prediction	0.841	ACCEPT
There are challenges in the integration of machine learning into cameras that can hinder weather predictive capabilities.	0.973	ACCEPT
The combination of AI and dynamical models (Mathematical weather data) enhances weather prediction capabilities.	0.839	ACCEPT
Integrating AI technology can enhance and improve Numerical Weather Prediction (NWP) systems by improving data assimilation, model optimization, and post processing outputs.	0.009**	REJECT
There are potential challenges or limitations to integrating Dependent Surveillance-Broadcast version 3 with Artificial Intelligence for weather data collection, such as data quality, privacy concerns, or technical difficulties.	0.135	ACCEPT
The integration of AI into the National Weather Service's operations could improve the accuracy and reliability of meteorological forecasts.	0.036**	REJECT

Legend: * with significant difference: **with very significant difference

Questions 16, 17, and 19 are considered to have no significant difference since their values are greater than the reference value which is 0.05. The value of question 20 is below the reference value, hence having a significant difference. Although question 18 is below the reference value, its value is also below the reference value for a very significant difference which is below 0.01. The study of Ziakkas et al. (2024) can be considered for these results, as the use of the National Weather Service integrated with AI is crucial for decision-making as it improves the forecast quality.

E. Significant Relationship from the Perceptions of Air Traffic Controllers and Pilots on Integrating AI Driven Weather Forecasting for Decision-Making

Table 13
Significant relationship from the perception of air traffic controllers on integrating ai-driven weather forecasting for decision-making

Groups Compared	Significance
Challenges of AI and Reliability of AI	0.01**
Reliability of AI and Predictability of AI	0.041*

Legend: * with significant difference: **with very significant difference

Pearson correlation is used to measure the significant relationship between Statement of the Problem number 1 and Statement of the Problem number 2 with a value of 0.01 which signifies that there is a very significant relationship between the perceptions of pilots and ATC on AI-driven weather forecasting for decision-making. The researchers assessed the questions that showed the correlation is significant and very significant. Question 10 showed a significant relationship for questions 4 and 5 with values of 0.03 and 0.016, respectively. Also, questions 7 and 14 showed a significant relationship with a value of 0.029. However, question 14 showed a very significant relationship for questions 4, 6, and 8 with values 0.01, 0.01, and 0.00, respectively.

Additionally, question 9 showed a very significant relationship for questions 10 and 11 with values of 0.003 and 0.00, respectively. Correlation is significant at the 0.05 level and very significant at the 0.01 level. This implies that the perceptions of pilots and ATC are very significant which is evident in the results from the questions that answer the challenges and reliability of AI in weather-related decisions and flight operations. This is also supported by the research conducted by Lin et al. (2023) which discusses the still uncertainty of the accuracy of the output of AI compared to the work of professionals and the research by McGovern, Tissot, & Bostrom (2024) which discusses the uses of the utilization of machine learning for weather prediction.

For the comparison of the Reliability of AI and Predictability of AI, question 10 showed significant relationships for questions 16, 18, and 19 with values of 0.048, 0.027, and 0.033 respectively. Other questions for Statement of the Problem number 2 also have significant relationships with Statement of the Problem number 3 questions such as questions 11 and 17, as well as 14 and 15 with values of 0.026, and 0.021 respectively. Questions 11 and 18 however, showed a very significant relationship with a value of 0.

All significant relationships are considered to be significant if the values are greater than 0.01 and equal to or less than 0.05. If the value is at the 0.01 level, the relationship is then considered very significant. For questions 11 and 18, the relationship of the questions is very significant, since both questions talk about the integration of AI technology and other innovations that improve the quality of sensing data. This can be observed from the study of Schultz et al. (2021) that advancements in meteorology such as geostationary and polar-orbiting satellites provide a great variety of data products. The study by Ziakkas et al. (2024) also discussed the use of Automated Decision Support AI to improve the decision-making process of pilots using real-time weather and turbulence information.

F. Gathered Data from the Respondents, why are there Significant Relationships and Significant Differences Between the Perception of Air Traffic Controllers and Pilots on Integrating AI-Driven Weather Forecasting for Decision-Making

Master Theme 1: Human Intervention or opinion still plays a significant role in decision-making, considering the use of artificial intelligence gives out accurate data

Superordinate Theme 1: Human Oversight

Informant 1: "One thing I'm not sure about AI is it can incorporate empathy."

Informant 2: "AI is based on a programming language and has flaws… human intervention still plays a significant role in terms of decision-making."

Informant 3: "While AI can provide accurate data, human judgment remains crucial…it may struggle with innovative solutions that require thinking outside the box."

Table 14
Master themes gathered data from the respondents, why are there significant relationships and significant differences between the perception of air traffic controllers and pilots on integrating AI-driven weather forecasting for decision-making

Master Theme	Superordinate Theme
Human Intervention or opinion still play a significant role in decision making, considering the use of artificial intelligence gives out accurate data	Human Oversight
Artificial Intelligence is reliable enough for weather prediction and be used by Pilots and Air Traffic Controllers for safe flight operations	Augmentation
The use of artificial intelligence is a common standard for flight operations software	Developability
Artificial Intelligence must introduce AI as reliable tool for aviation professionals considering that it is new to the aviation industry	Innovation
The source of data, whether AI generated or human interpreted, can significantly influence the decision making.	Human dependent
Air quality disrupts flight operations and is a valuable parameter for meteorological forecasts for flight operations	Hazard
Integrating AI technology enhances weather prediction	Quick Process
A common unit for NWS in the Philippines that could be integrated with artificial intelligence	Weather

The master theme discusses the significant role of human intervention or opinion in decision-making about the accuracy of artificial intelligence in providing accurate data. The informants expressed their concerns about the reliability of AI alone since AI is only limited to what they're programmed to do and human oversight is still required to ensure safe operations furthermore, the informants think that AI can assist in decision-making. A journal article by Jarrahi (2018) states the complementarity of humans and AI and examines how each can bring its strength to organizational decision-making processes typically characterized by uncertainty, complexity, and equivocality. Additionally, it is also observed in research conducted by *Lin, Y. et al. (2023)* where there is still uncertainty in the accuracy of AI output compared to the output by human work professionals.

Master Theme 2: Artificial Intelligence is reliable enough for weather prediction and be used by Pilots and Air Traffic Controllers for safe flight operations

Superordinate Theme 2: Augmentation

Informant 1: "Incorporating it on weather prediction for "assistance" in gathering or producing data, yes, but for it to be 100% reliable alone, I'm not so sure about it."

Informant 2: "Artificial intelligence can be considered reliable in terms of weather predictions that can be used in day-to-day flight operations… there should be human double checking of the data before the data is being relied on by the system."

Informant 3: "Yes, AI can significantly enhance weather prediction accuracy, but it's important to use it as a tool, not a replacement for human expertise."

Master theme 2 discusses the reliability of Artificial Intelligence for weather prediction that can be used by pilots and air traffic controllers for safe flight operations. The informants emphasized that AI can improve weather prediction reliability however, the informants emphasized that it cannot stand on its own and should have a human to oversee its output. They also highlighted that it can provide assistance and should be used as a tool and not replace human expertise. This is evident in McGovern et al (2019) AI2ES research in explainable AI which aims to establish trust in the use of AI for professionals related to the field. Research by Kumar et al. (2022) also states that Artificial Intelligence is rapidly dominating the technological landscape where with its interoperability, it can be reliable to be used by professionals such as pilots and air traffic controllers for safe flight operations.

Master Theme 3: The use of artificial intelligence is a common standard for flight operations software

Superordinate Theme 3: Developability

Informant 1: "Use of AI can be a common standard in the field once it is fully developed and assured based on its research and development."

Informant 2: Artificial intelligence can be a standard in flight operations software... artificial intelligence developers must be partnered with different companies that offer flight planning software.

Informant 3: Collaboration between aviation industry stakeholders, including airlines, manufacturers, and regulators, is crucial to develop common standards and protocols.

The master theme 3 discusses the use of artificial intelligence as a common standard for flight operations software. The informants stated that the research and development of AI and integrating it with other developers and stakeholders can increase the reliability of AI and once it is fully developed, it can be integrated into flight operations software and be a common standard in the field. This is evident in research by *Snezhanaszillat. (2024)* where AI can be reliable through addressing concerns and continuous system refinement.

Master Theme 4: Artificial Intelligence must introduce AI as a reliable tool for aviation professionals considering that it is new to the aviation industry

Superordinate Theme 4 : Innovation

Informant 1: "AI developers need to advertise it in a way that the industry can consider trusting...proof of study on how it is successfully used to provide accurate data assistance."

Informant 2: "AI developers can start introducing their latest innovation by attending aviation conferences, summits, or conventions... build their network…"

Informant 3: "AI developers can build trust and acceptance by clearly communicating the limitations and uncertainties of AI models…"

The master theme 4 discusses the introduction of AI as a reliable tool for aviation professionals considering that it is new in the industry. The informants expressed their recommendation to introduce the technology by attending large-scale aviation events such as conferences and building a network by showing that AI can be trusted and be used in the field. Also, to be transparent on its limitations and uncertainties to open up development opportunities. This is emphasized in *McGovern et al (2019)* AI2ES research in explainable AI where its goal is to establish trust in the use of AI in professionals' field of work which will significantly improve the reliability of AI.

Master Theme 5: The source of data, whether AI-generated or human-interpreted, can significantly influence decision-making.

Superordinate Theme 5: Human Dependent

Informant 1: "I think their results won't be entirely different, and neither will be wrong. The only difference will be AI's data-based, it will produce results based off the data you feed them so most likely they'll be very standard about decision-making, probably not taking into consideration other things that's off the book. While human-interpreted results can be similar to AI, there will be something about it that provides the complexity of human intelligence based off from one's experience."

Informant 2: "As of this moment I would like to consider human-interpreted results because I do believe that the human who interprets the results is an expert in their field. Given AI is newly introduced in the aviation industry, for me, I will consider implementing AI as early as now is still in a trial phase unless AI in aviation is being used for a period approximately of five to ten years and found in different research that AI usage in the industry has less to no error."

Informant 3: "AI-based data can provide more objective and quantitative information, while human interpretation can offer contextual understanding and subjective judgment. The ideal approach is to combine both: use AI to process and analyze data, and then use human expertise to interpret the results and make informed decisions."

The master theme 5 discusses the human dependability of AI in terms of decision-making. Since AI provides the necessary data for humans to interpret, the informants all agreed that human intervention or intelligence provides the most crucial component in terms of decision-making. Human intelligence, as the informants mentioned, provides inputs that even AI can not sense or provide, which is experience. Hence, human intervention as the final input for decision-making. As mentioned by Kumar et al. (2022), the use of AI aids in providing efficient solutions for problems that arise in different departments of the aviation industry such as air traffic management.

Master Theme 6: Air quality disrupts flight operations and is a valuable parameter for meteorological forecasts for flight operations

Superordinate Theme 6: Hazard

Informant 1: "Yes. In terms of air quality based on its density, it is still one of the factors that's why it is important to give information up-to-date to pilots and other airmen about this so they'll know how to maneuver their way around their aircraft's performance. And if air quality is based on the pollutants index, I'm not so sure although it is possible if there are gasses that can affect the density of air. So yes, air quality can be a valuable parameter for flight operations.."

Informant 2: "Yes, air quality can disrupt flight operations and air quality is a valuable parameter for meteorological forecasts for flight operations. One good example is the explosion of taal last 2020-2021 if I remember correctly. The eruption of a volcano can affect air quality because of the gas components it emits sulfur dioxide which mixes with the air. Those gasses are harmful to passengers and the aircraft engine as well. I remember that time when most of the flights were canceled."

Informant 3: "Yes, poor air quality can disrupt flight operations by reducing visibility, affecting engine performance, and creating hazardous conditions for aircraft. Incorporating air quality data into meteorological forecasts can help pilots and air traffic controllers make informed decisions and avoid potential risks."

Master theme 6 discusses poor air quality as a hazard to flight operations. Two of the informants have mentioned that gasses can affect the air quality. Based on the responses of the informants, air quality can also affect the performance of the engines of the aircraft since the air may contain different debris that can harm the components of the engines, ultimately affecting the integrity of the engines. This can be integrated with the study of Albahri et al. (2024) the concept of artificial intelligence, specifically through predictive models such as explainable artificial intelligence, can encompass even natural disasters such as volcanic eruptions that emit different gasses which can be hazardous to the performance of the aircraft.

Master Theme 7: Integrating AI technology enhances weather prediction

Superordinate Theme 7: Quick Process

Informant 1: "I think AI can help with data accuracy and faster generation. Incorporating it slowly by feeding it off data from the basics just to see how it goes from there."

Informant 2: "Integrating AI technology can have a huge impact in terms of enhanced weather reports or predictions. Since AI can collect several data in a short period of time which can make its analysis algorithm more accurate."

Informant 3: "AI can enhance weather prediction by identifying complex patterns and trends that may not be apparent to human forecasters. AI can lead to more accurate and timely forecasts, especially for short-term predictions."

The master theme 7 discusses how artificial intelligence is reliable for its quick processing of data. The informants agreed that artificial intelligence produces timely results which is a significant factor in terms of operations in the field of aviation, as on-time-performance is crucial for each airline. It has been discussed that artificial intelligence produces real-time data, this is a huge aid to aviation professionals as they need up-to-date and quick processing data. Ziakkas et al (2024) also made note that Weather Prediction AI uses radar, satellite, and numerical weather prediction models, these are important components that produce accurate and timely weather forecasts.

Master Theme 8: A common unit for NWS in the Philippines that could be integrated with artificial intelligence

Superordinate Theme 8: Weather

Informant 1: "Here in the Philippines, I believe we have what we call AWOS for generating real-time meteorological data. I think AI incorporation can start from there, to check and see how it can help in providing data to airmen."

Informant 2: "The equivalent of the NWS here in the Philippines is the PAGASA. I do believe that in time, PAGASA can consider adding AI technology to their equipment for data analysis to be more accurate."

Informant 3: "PAGASA could serve as a common unit for weather forecasting in the Philippines. By integrating AI technology, PAGASA can improve the accuracy and timeliness of its forecasts, benefiting a wide range of sectors, including aviation."

The master theme 8 discusses the alternative unit of NWS in the Philippines. Two of the informants answered PAGASA which is the government agency that gives weather forecasts to the general public. One informant answered AWOS or Automated Weather Observing System, a system that provides aviation professionals and pilots real-time information for weather at a certain airport. Both answers are considered to give data on weather forecasting and monitoring. In the study of Murugan et al. (2022), weather monitoring is considered to be an analytical method or statistical measure, not a binary decision.

4. Discussion

A. Conclusions

Based on the results and analysis, the following were concluded:

1. The findings underscore the importance of combining traditional forecasting techniques with modern AI tools to tackle aviation weather challenges. While AI shows promise, it can't stand alone—data limitations and a lack of transparency, especially regarding Explainable AI, remain major hurdles. By blending both traditional and AI-driven approaches, the industry can strike a balance that improves accuracy without over-relying on any single system. At the same time, there's concern about the current capabilities of AI to function independently, particularly in critical decision-making. This highlights why human oversight is not just beneficial but necessary. Overall, these insights suggest that refining the integration of AI in aviation meteorology has huge potential, not just for better forecasts but for improving efficiency across the board.
2. The results show that AI technology plays a vital role in aircraft operation. It provides predictions on weather conditions, helping and guiding the system in better understanding and decision-making. AI technology is very efficient, especially when combined with conventional forecasting techniques. With human intuition mixed with AI technology, a much better weather prediction and forecast in the aviation industry emerges.
3. Based on the data gathered from the professional respondents, the results show that they agreed on having and implementing artificial intelligence (AI) to identify and highlight unpredictable weather patterns. It may enhance the predictions significantly, which promotes safety and reliability that contribute to the improvement of performance and competitiveness of airports. Having the help of artificial intelligence in predicting weather, increases the accuracy of predictions and enables airports to have a better preparation for adverse weather conditions. This results in improvements to the overall services and performance of airports, which ultimately enhance customer satisfaction.
4. The findings indicate notable differences in perceptions between pilots and air traffic controllers regarding the integration of AI-driven weather forecasting for decision-making. These differences emphasize varying levels of confidence in AI's reliability, effectiveness, and potential applications in aviation operations. Pilots generally expressed greater agreement with the importance of combining forecasting methods to improve weather prediction accuracy, reflecting their hands-on reliance on precise weather data for operational safety. Air traffic controllers, however, also recognized the value of hybrid approaches but to a slightly lesser extent. While pilots leaned toward skepticism regarding AI's ability to operate autonomously in decision-making processes, air traffic controllers showed a slightly higher level of agreement, suggesting a more optimistic view of AI's potential role in future operations. The results also highlighted diverging views on traditional versus AI models. Pilots perceived traditional models as more reliable than AI-driven systems, whereas air traffic controllers favored the efficiency of AI technologies for daily tasks and decision-making. Overall, these differences in perceptions underscore the need for collaborative discussions between pilots and air traffic controllers to align on AI integration strategies. Addressing these varying perspectives can foster a shared understanding, ultimately ensuring the effective implementation of AI-driven weather forecasting in aviation.
5. The researchers concluded that the perceptions of both Air Traffic Controllers and pilots on the integration of AI-driven weather forecasting for decision-making intersect on the challenges, reliability, and predictability of AI. Artificial intelligence, an

emerging technology developed by humans, is relatively new, especially in the aviation industry which regularly handles safe flight operations which also involve possibilities of unpredictable events. There is still uncertainty in the use of AI however, there is big room for improvement in providing output accuracy and developing AI to be reliable in assisting aviation professionals in meteorological decision-making for flight operations.

6. The relationship between the perceptions of Air Traffic Controllers and Pilots on the use of AI indicated that it cannot replace humans and is unreliable on its own and therefore should be overseen by a human. With AI being a human creation, it can be developed and improved further to ease the burden of humans in work settings.

B. *Recommendations*

Based on the discussed conclusions, the recommendations are as follows:

1. Air traffic controllers are trained to evaluate and cross-check AI outputs against their human knowledge. Such AI models must then be updated and trained using a range of weather data to increase their forecasting skills, especially concerning extreme events. There should be a proper communication channel that must be established between air traffic control and AI systems so that the controller continues to influence significant decisions. Enhancing the explainability and openness of AI models will then build trust and enable controllers to make choices using meteorological data produced by AI.
2. The pilots would thus be endowed with timely, actionable knowledge through customizable alerts and risk assessments for specified flight routings. AI-driven collaborative decision-making in the aircraft cockpit and between the aircraft and air control would result in faster reactions in hazardous conditions. Finally, over time, weather forecasts can be improved and safety increased through ongoing learning and adaptation of AI systems based on pilot feedback and real-world data. These strategies will enable pilots to fly with more accuracy and confidence in unexpected weather.
3. Airlines companies should prioritize the collection of first-rate, real-time weather data and ensure that it is integrated without interruption into AI models. To maximize their accuracy, they should make use of hybrid AI models that combine machine learning with traditional meteorology techniques. Prioritization of transparency and explainability in AI-driven insights will ensure trust and understandable model outputs to meteorologists and decision-makers. Airlines must focus on real-time data processing to make decisions in due time over flight planning and operation and adapt fast to changing weather conditions. Last but not least, funding training and encouraging cooperation between meteorologists and AI specialists would guarantee that these AI insights were converted into workable plans that enhance overall operational effectiveness and security. Airline companies should provide more collaborative forums for pilots and air traffic controllers to share ideas and get on the same page regarding AI-driven weather forecasting.
4. Flight operations officers should encourage joint training to better clarify the role of AI as a decision tool, to adopt AI in a manner that complements rather than supplants human judgment, and to establish feedback loops that continually bring out enhancements of the system from both the ATC and pilot perspectives. Therefore, how AI is integrated will, to a large extent, determine whether it is effective and trusted, thereby ensuring operational safety and efficiency.
5. Future researchers should explore these differences by examining trust in AI, cross-disciplinary studies, and training programs that would combine human expertise with AI technologies. Additionally, simulation-based studies could assess the practical effects of AI while simultaneously addressing the regulatory and ethical challenges to ensure its adoption into aviation operations goes smoothly. In addition, Future research should focus on building pilot trust in AI by ensuring transparency, reliability, and user-friendly interfaces. Engaging pilots in development and testing and tailoring training to emphasize AI's assistance, rather than replacement, of their judgment in decision-making will be essential for building confidence and ensuring smooth adaptation to the technology.
6. Future researchers should focus on building pilot trust in AI by ensuring transparency, reliability, and user-friendly interfaces. Engaging pilots in development and testing and tailoring training to emphasize AI's assistance, rather than replacement, of their judgment in decision-making will be essential for building confidence and ensuring smooth adaptation to the technology.

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