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Evaluating Flight Crew Decision-Making Through Part 121 Taxi Operations

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Evaluating Flight Crew Decision-Making Through Part 121 Taxi Operations

By

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This thesis was prepared under the direction of the candidate's Thesis Committee Chair, Dr. Michael D. New, and has been approved by the members of the thesis committee. It was submitted to the College of Aviation and was accepted in partial fulfillment of the requirements for the Degree of Master of Science in Aviation.

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Abstract

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With the mandate of Automatic Dependent Surveillance-Broadcast (ADS-B) going into effect at the start of 2020, commercial companies have been able to log and store information on aircraft identification, airspeed, heading, and altitude all in one database.to Now, anyone can access previously hard-to-obtain flight data for analysis using a commercially available database. While ADS-B provides information on “what is happening,” information on “why” flight crews operate aircraft in a certain way is not incorporated into ADS-B.

The National Aeronautics and Space Administration’s (NASA) Aviation Safety Reporting System (ASRS) collects reports written by flight crews, Air Traffic Control Specialists, and other users of the National Airspace System. The reports are collected and deidentified by NASA and then published, describing what the reporter sees and thinks during normal operations, events, and incidents. This study examined the ground speed at which a flight crew chose to enter a turn during taxi operations based on taxiway intersection angle and surface contamination. Additionally, this study explored whether there was a way to connect ASRS and ADS-B.

Eighty-eight flights were split into four different groups based on their taxiway intersection angle and the surface conditions during taxi operations. A two-way Analysis of variance was conducted to analyze statistical differences between group means for the ground speed entering a turn. A significant interaction existed between taxiway angle and surface contamination, indicating differences in the group means. As the taxiway intersection angle increased, the ground speed significantly decreased for dry surface conditions.

Barriers currently present in the ASRS system prevented the researcher from linking any ADS-B data to a report using the information found in that ASRS report. NASA can improve the ASRS system by utilizing commercially available ADS-B data while still keeping the reporter confidential. Future research is necessary to expand this study outside of the United States and to explore the differences between taxi operations for international commercial air carriers.

Keywords: ASRS, ADS-B, aviation, taxiway intersection angle, surface contamination

Dedication

This thesis is dedicated to my family and everyone who has helped me grow into who I am today. I cannot put into words my gratitude for everyone who has been a part of my journey.

Acknowledgments

This thesis could not have been possible without my committee chair, Dr. Michael New, and my committee member, Dr. Barbara Holder. Their support and expertise allowed me to come up with this study. Thank you both for helping me through this challenging process.

I am deeply grateful to Drs. Donald Metscher, Dahai Liu, Andrew Dattle, Joao S.D., and Scott Winter for their unwavering encouragement during my graduate education at Embry-Riddle. Your encouragement was crucial in my journey to complete this research and degree. I would also like to thank Ms. Bee Bee Leong, Ms. Flavia Danksine, and Ms. Donna Ferrell for their continuous motivation throughout my graduate education at Embry-Riddle.

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Chapter I: Introduction

Operating an airline safely is crucial for success. While complete safety cannot be guaranteed, steps can be taken to mitigate the operational risk associated with taxiing. In June of 2018, a part 121 carrier was taxiing into a terminal after landing in heavy rain. The aircraft proceeded towards the terminal and during a turn, the aircraft hydroplaned and experienced a taxiway excursion. The report from the flight crew indicated that the captain was "cognizant of turning at a safe speed' yet they still experienced the excursion (National Aeronautics and Space Administration [NASA], 2018a).

With the mandated use of Automatic Dependent Surveillance–Broadcast (ADS-B), aircraft can be tracked continuously worldwide. This technology allows for reporting flight identification, current position, altitude, and velocity, all without interactions between the aircraft and flight crew. From this mandate, commercial service providers have been created, allowing anyone to access this information on flights. Airlines can now analyze previously hard-to-obtain data and examine other airlines. While the new capabilities are highly beneficial, ADS-B can only explain what happens during normal operations, significant events, and incidents. If there was a way to explain "the why" in conjunction with ADS-B, then a better understanding of flight crew decision-making could be achieved.

The National Aeronautics and Space Administration's (NASA) Aviation Safety Reporting System (ASRS) collects reports written by flight crews, flight attendants, and other users of the National Airspace System, explaining why normal operations, events, and incidents happen. However, ASRS reports are narrative and do not contain any flight data. Additionally, the ASRS system deidentifies reports in an effort to promote the sharing of events while also being nonpunitive. While the reports are deidentified and detail “the why,” there is no way to connect what the reporter says with any flight record to explain “the what.” If a method for connecting ADS-B data with ASRS reports could be established, then understanding both the “what” and “why” can be achieved for normal operations, events, and incidents.

This study will attempt to do two things. First, it will evaluate flight crew decision-making by analyzing groundspeed during taxi operations in different conditions. Second, it will attempt to connect ASRS reports with their respective ADS-B records to explain both the “what” and “why” of aviation operations.

Statement of the Problem

ADS-B provides a new resource for the analysis of all flight operations both in the air and on the ground. Taxiing around an airport is one of the most intense parts of a flight, especially if the conditions are less than ideal. This study will examine flight crew decision-making during taxi operations through an analysis of the ground speed entering a turn while taxiing and how the surface conditions and intersection angle affect the flight crew’s decision of what ground speed to use.

While ADS-B provides information on what a flight crew is doing, there is no reliable way of examining why flight crews are operating in a certain way. In order to learn from normal operations, understanding both the “what” and “why” is critical. Currently, there is no connection between the ASRS database and an ADS-B data source. This study will attempt to develop a method for taking the deidentified narrative data from ASRS reports and connecting it to ADS-B data, creating a new way of analyzing both the “what” and “why” during aviation taxi operations.

Purpose Statement

The purpose of this study is to examine flight crew decision-making when turning during taxi operations. This study operationalized the flight crew's decision-making by using the groundspeed of a flight that was entering a turn. The two factors that will be examined are surface contamination and taxiway angle. ASRS reports have shown that both surface contamination and taxiway angle have the potential to influence the decision-making process while taxing (NASA, 2022a; NASA, 2022b, & NASA. 2018b).

Significance of the Study

Many studies analyzed the behavior of pilots and how risk mitigation strategies can be beneficial (Odisho et al., 2021; Holmes & Stewart, 2008). While many of these studies use ADS-B data or ASRS reports, they seldom use both. Although the results of those studies have been able to increase aviation safety by creating predictive models or reducing risk, they fail to establish a connection between ADS-B and ASRS. Additionally, the effect of significant factors in the airline operating environment can be evaluated for flight crew decision-making as a way of demonstrating the potential benefits of including ADS-B data in ASRS reports.

Research Questions

The following research questions will be investigated.

RQ1: Does surface contamination and taxiway intersection angle influence a flight crew's decision on what ground speed to enter an intersection during taxi operations?

RQ2: Can ADS-B data be connected to ASRS to understand incidents and accidents better?

To investigate pilot decision-making, the groundspeed entering a turn during taxi will be compared with different taxiway angles and different surface contamination.

Hypotheses

The following null hypotheses will be explored.

$H_0$1: There is no statistically significant difference in flight crew decision-making during taxi operations due to differences in taxiway intersection angle.

$H_0$3: There is no statistically significant difference in flight crew decision-making during taxi operations due to differences in surface contamination.

$H_0$3: The information in an ASRS report cannot be used to identify the ADS-B records for that report.

In addition to investigating the taxiway intersection angle and surface contamination for simple main effects ($H_0$1 and $H_0$2), any interaction between them will be evaluated.

Delimitations

This study will only focus on flights in the United States of America. Additionally, the study will focus on Part 121 operators. This is due in part to the data availability as the use of ADS-B is required for all flights, as the airports that Part 121 operators use have more reliable ground coverage for ADS-B. Select airports of different sizes from around the United States will be used; however, small, general aviation-focused airports will not be used.

Limitations and Assumptions

The resulting model will only be able to be used by Part 121 operators due to the ADS-B data. Significant work will have to be done in order to adapt the model to all aviation operations. This is due to the nature of operations in the National Airspace System; with the wide variety of operations from general aviation to military, this study does not have access to all of its operational data.

It was assumed that all ADS-B data was accurate and correct. This assumption is justified by the Federal Aviation Administration's requirement that all aircraft output an ADS-B signal. Additionally, all other data, including historical weather data, airport geometry information, and the content of ASRS reports, are reported accurately.

Summary

ADS-B can provide valuable information to the entire air transportation industry on how users of the National Airspace System operate. Evaluating flight crew decision-making during taxi operations will demonstrate how ADS-B can be used to understand what flight crews are doing across the commercial air transportation industry. However, ADS-B only provides the 'how' for normal operations, events, and incidents. Attempting to connect ADS-B to ASRS will ultimately expand upon the analysis of flight crew decision-making by adding the "why" to these operations.

Chapter II will investigate some of the past research done on flight crew decision-making. Additionally, the chapter will cover the theories behind the framework and hypotheses of this study. Chapter III will cover the methodology, including the target population, sample, data collection, and data analysis.

Definitions of Terms

Part 119	Code of Federal Regulations, Title 14, Part 119 – Certification: Air Carrier and Commercial Operators. "Applies to each

	person operating or intending to operate civil aircraft as an air carrier or commercial operator.” (Part 119 – Certification: Air Carriers and Commercial Operators [Part 119], 2023)
Part 121	Code of Federal Regulations, Title 14, Part 121 – Operating Requirements: Domestic, Flag, and Supplemental Operations. “The domestic, flag, and supplemental operations of each person who holds or is required to hold an Air Carrier Certificate or Operating Certificate under part 119.” (Part 121 – Operating Requirements: Domestic, Flag, and Supplemental Operations [Part 121], 2023)
METAR	A METAR is a routine meteorological report conducted at airports near the top of every hour. Information on the prevailing wind, temperature, precipitation, and cloud coverage is reported for use by pilots and air traffic controllers.

Movement Area	The area in an airport that is to be used for take-off, landing, and taxiing. This area does not include any ramp or apron areas.
Temperature-Dewpoint Spread	The difference between the temperature and the dewpoint at a height of two meters above the runway surface, as reported by the ATIS system.
Tiller	A control device inside the flight deck of a large commercial airliner. Much like how a steering wheel controls the front wheels of a car, the tiller controls the direction of the front wheels of an aircraft, superseding the input by the rudder pedals.

List of Acronyms

ADS-B	Automatic Dependent Surveillance-Broadcast
AIBD	Accident Investigation Board Denmark (Havarikommissionen)
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATIS	Automatic Terminal Information System
DAB	Daytona Beach International Airport
CSV	Comma-separated Values
FAA	Federal Aviation Administration
FICON	Field Condition Report

NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Air Mission
NTSB	National Transportation Safety Board
NWS	National Weather Service
VMC	Visual Meteorological Conditions

Chapter II: Review of Literature

Taxi operations are influenced by numerous factors, including airport geometry, weather, and visibility. This chapter starts out by looking at airport geometry and how taxiway design can influence taxi operations. The chapter then transitions towards abnormal taxi operations, including nonnormal conditions and low visibility operations. Finally, the chapter concludes with an evaluation of the ASRS system and how it works.

Taxi Operations

Operating in a safe environment is critical for success. With the increasing demand for air travel, airports are becoming busier than ever. Using ADS-B data allows for an analysis of flight crew decision-making and performance. During taxi operations, there are numerous factors that a flight crew takes into account during taxi operations.

Airport Geometry

Airport geometry refers to the way that airports are laid out. While there are standards for airport construction, there are nonstandard practices that airports around the world follow. The Federal Aviation Administration has identified seven main configurations at airfields that lead to challenges for pilots:

- Direct access to runways from ramp areas
- Short taxi distance from ramp or apron to runway
- Taxiway intersecting runway at non-right angle
- Wide expanses of taxiway pavement along a runway
- Short distance between parallel runways
- Runway thresholds in close proximity
- Hold short lines in unexpected places (FAA, 2023)

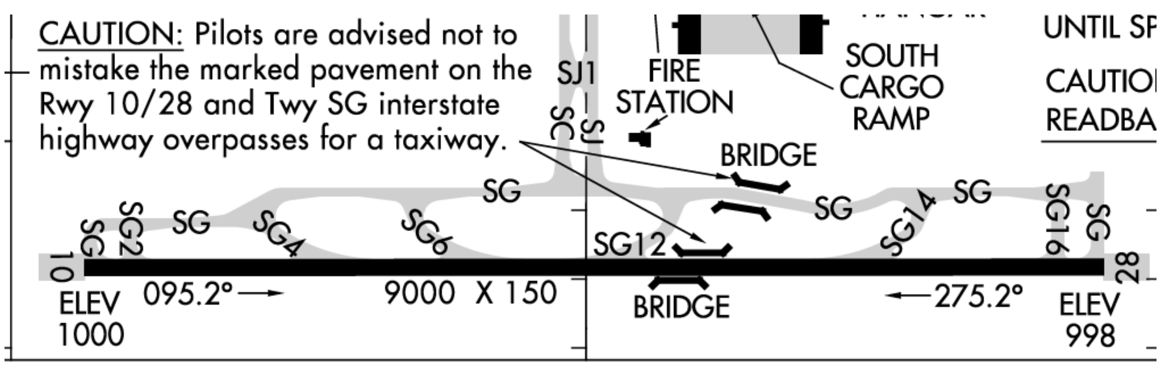
While each of the seven is present across airports globally, one of the more common configurations is taxiway intersection runways at non-right angles. Many runways have what is called a rapid exit taxiway or highspeed exit. These taxiways are angled off the runways so that an aircraft can take the turn at a higher rate of speed. The goal behind these highspeed exits is to increase airport capacity in the growing aviation industry.

Rapid Exit Taxiways

Rapid exit taxiways were developed as a way of increasing airport capacity. These taxiways serve as a way for aircraft to vacate the runway without slowing to the proper speed to make a 90-degree turn. While the turn after the highspeed exit varies, the initial turn off the runway is normally 30 degrees. An example of a highspeed exit is shown in Figure 1.

Figure 1

A Collection of High-Speed Exits from KATL's Runway 10/28



Note. From *Hartsfield-Jackson Atlanta INTL (KATL) airport diagram*, by Federal Aviation Administration.

Rapid Exit Taxiways Example. On November 21st, 2012, an Airbus A319-131 was landing at Copenhagen Airport (EKCH) and, upon turning onto the high-speed exit, misjudged the following turn and exited the taxiway. Both the aircraft and airport were damaged (Havarikommissionen [AIBD], n.d.).

This incident happened on taxiway B4 after turning off of Runway 22L. At the end of the straight part of the highspeed exit, the pilot flying could not keep the aircraft on the centerline of the taxiway and skidded off the taxiway. The Automatic Terminal Information System (ATIS) indicated that Runway 22L was damp and to "expedite vacating the runway" (AIBD, n.d.). The Accident Investigation Board Denmark (AIBD) determined that ineffectual braking contributed to the high ground speed at the end of the straight part of the B4 taxiway.

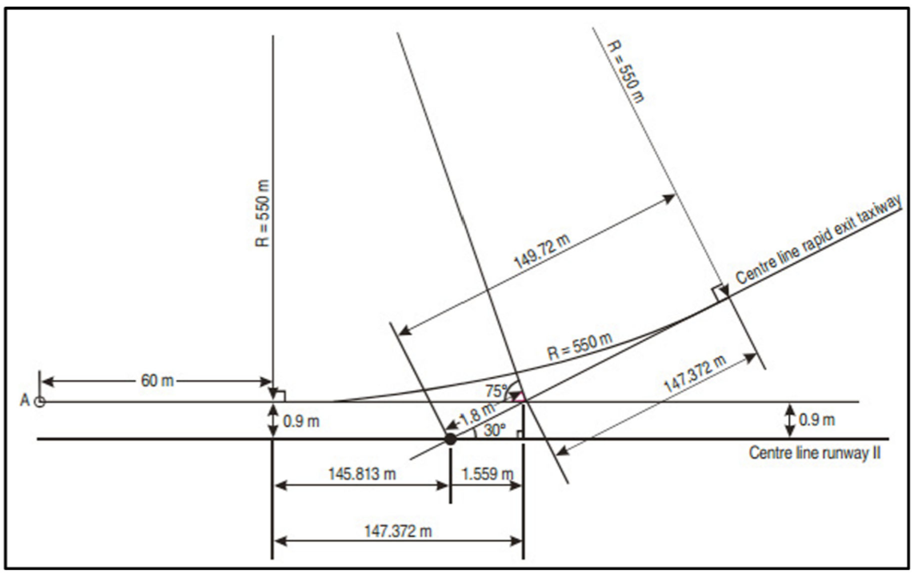
The AIBD calculated that the aircraft was traveling at a ground speed of 12 knots, faster than the curve design allowed, leading to the incident. There was no limitation sent in the Flight Crew Operating Manual or the Airplane Flight Manual; however, the A320 family Flight Crew Training Manual states that for turns of 90 degrees or more, the aircraft should be slowed down to 10 knots or slower (AIBD, n.d.).

As a result of this incident, Copenhagen's airport issued a Notice to Air Mission (NOTAM) stating that the curved end of the highspeed exit is only designed for operations at or below 15 knots in dry conditions (AIBD, n.d.).

Rapid Exit Taxiway Design. The design of rapid exit taxiways has varied over time. Two of the notable changes are the degrees of the turn off the runway and the recommended speed. The current recommendation for the rapid exit taxiway is that the taxiway be constructed to a centerline radius of 550m, with the resulting taxiway turning off the runway at a 30-degree angle (Figure 2). Over time, the recommended speed for the initial turn onto the rapid exit taxiway has increased. With the current design, the recommended speed is 26.7m/s or 52 knots (Galagedera et al., 2020).

Figure 2

Recommended design of a rapid exit taxiway



Note. From *Rapid Exit Taxiways – Aerodrome Design Manual,* International Civil Aviation Organization. https://skybrary.aero/sites/default/files/bookshelf/3090.pdf

Abnormal Taxi Operations

Moving an aircraft around an airport can be a complicated task. In addition to complex airport geometry, abnormal operations can influence the risk associated with taxi operations.

Winter Operations

Operating aircraft during the winter months has its own set of challenges, including low temperatures, dewpoint spreads, freezing precipitation, and contaminated surface conditions. One problem during winter weather operations is measuring surface friction. Similar devices used on the same surface result in different friction estimates. The uncertainty provided by these different measurements is taken to be scientific truth by pilots, leading them to risky situations (Accident Investigation Board Norway [AIBN], 2011). Additionally, the closer the temperature-dewpoint spread, the more unpredictable the surface friction measurements become (AIBN, 2011). None of the internationally recognized measuring devices are reliable on all types of contamination. Research has shown that when the temperature-dewpoint spread is less than three degrees Kelvin, and the contamination is loose or layered, it greatly increases the uncertainty of surface condition measurements (AIBN, 2011).

The opinion of the Accident Investigation Board of Norway is that many incidents relating to slippery conditions occur because of the oversimplification of the nonstandard surface conditions. There is much uncertainty in the measurements that are taken with winter weather operations, and safety margins are decreased when operating in these conditions (AIBN, 2011).

Reduced Visibility Taxi Operation

Visibility is critical for moving around an airport. Low visibility can be more than the weather, with some airports lacking appropriate taxiway lighting, making navigation complicated. As noted by Andre, some pilots find that “Low-visibility taxi situations are the hardest” (1995). Although these situations are deemed harder than normal operations, pilots recognize the risk involved with low-visibility operations and have been shown to taxi at one-half to one-third of their normal taxi speeds (Andre, 1995).

Even when the outside visibility is adequate for faster speeds, pilots have stated that at some airports, the visibility of signage and other location indicators reduce the safety margins just as much as being unable to see outside (Andre, 1995). When these situations happen, pilots must use all the tools possible while taxiing. The primary tool that pilots would turn to in the low-visibility operations would be their map (Andre, 1995). Using the map, pilots can safely determine where they are at an airport and develop their mental model of what is around them. While at complex airports such as Chicago O'Hare or San Francisco International Airport, the combination of weather and inadequate airport signage can slow taxiing to a crawl. Flights operating out of the San Franciso airport have reported taxi times upwards of an hour due to dense fog and unclear signage (Andre, 1995). Overall, flight crews must consider the increased risk when operating in low-visibility environments, and most do so by slowing the taxi speed down.

On the 15th of December, 2015, Southwest Airlines flight 31 demonstrated the severity of risk associated with low-visibility operations. Prior to Southwest's arrival at Nashville International Airport (BNA), the Air Traffic Control Tower inadvertently turned off the taxiway lights for a portion of the airport. (National Transportation Safety Board [NTSB], 2017). Upon landing, the Southwest Airlines flight was taxiing towards the gate area when they entered the area of unlighted taxiways. The crew was unable to see the appropriate taxiway, so they left the paved area and came to rest in a grassy drainage ditch (NTSB, 2017).

Previous Models

Previous work has been done illustrating the complex system that encompasses an airport. Within the complex National Airspace System, there are a multitude of subsystems that can be modeled. One system that has been modeled is the movement area. Within the movement area of an airport, multiple functions happen simultaneously, including taxiing. Wilke et al. developed a risk assessment tool for operating within a movement area (2014). Within this model, taxi operations consisted of multiple different smaller tasks, including:

- Commanding aircraft movement
- Monitoring other traffic and obstacles
- Communication with ATC for clearance
- Monitoring distance from other obstacles (Wilke et al., 2014)

While there are numerous tasks to handle, maintaining control of the aircraft's movement is the crew's top priority. The model created by Wilke allows stakeholders in airport surface operations to determine the operational risk as a baseline for operational efficiency studies. The final iteration of the model allows for the identification of key factors in operations within the surface area of an airport. Identification of factors allows for adequate planning and mitigation of risk for operators, especially during the taxi phase of flight (Wilke et al., 2014).

Additionally, Cheng et al. (2001) explored the idea of improving taxi times and precision as a way of combatting the increasing surface traffic problem at airports. The main controls for taxiing around an airport are the throttles and brakes for speed and the tiller and differential braking for directional control. Through the use of different techniques, pilots were able to decrease the time it took to complete a taxi assignment; However, the positioning error increased every time the taxi speed increased (Cheng et al., 2001). With the use of the model, Cheng et al. (2001) were able to prove that increasing the taxi speed up to a certain limit would enable taxi operations to travel at a greater rate of speed without compromising control of the aircraft.

Aviation Safety Reporting System

Aviation safety reports are one of several resources for understanding normal operations, significant events, and incidents. While a flight crew is not required to submit them for all situations, some do as a way of inspiring change and sharing knowledge. For incidents that result in a report being filed, the current ASRS system allows for the deidentification of information that could be used to identify who the flight crew is. This deidentification allows for the reports to be anonymous in nature and acts as a way of encouraging them to be submitted. However, some deidentification can make it hard to understand the context of reports and can cause reports to be unusable.

ASRS serves as a way for users of the National Airspace System to provide reports of potential safety hazards as well as incidents that may not need an investigation by the National Transportation Safety Board (NTSB). The general purpose of the ASRS is to "collect, analyze, and respond to voluntarily submitted aviation safety incident reports to lessen the likelihood of aviation accidents (NASA, 2023a). In order to help facilitate this process, the federal government has implemented policies that protect reporters. When the Federal Aviation Administration (FAA) implemented some of these policies, they established NASA as a third-party recipient of the reports, in which they can remove any information necessary to protect the anonymity of the reporter and all parties involved in an incident (NASA, 2023b).

Confidentiality of the ASRS

Within the ASRS, anyone, not just flight crews, can report safety issues. Multiple different parties, including air traffic controllers, flight attendants, mechanics, and ground personnel, to name a few, are encouraged to submit a report (NASA, 2023c). When a report is sent to NASA, they are closely guarded to protect the reporter. To protect an individual, all personal names, dates, times, and related information that could be used to identify are either completely removed or generalized (NASA, 2023c).

Additionally, the FAA has stated that they will not use ASRS information against reporters if any rules or regulations are broken. Past history has shown that the FAA will also waive fines and penalties for unintentional violations that are reported to the ASRS (NASA, 2023c). With the use of these incentives, the FAA hopes that more people will report to the ASRS and increase the overall safety of the NAS.

Composition of ASRS Reports

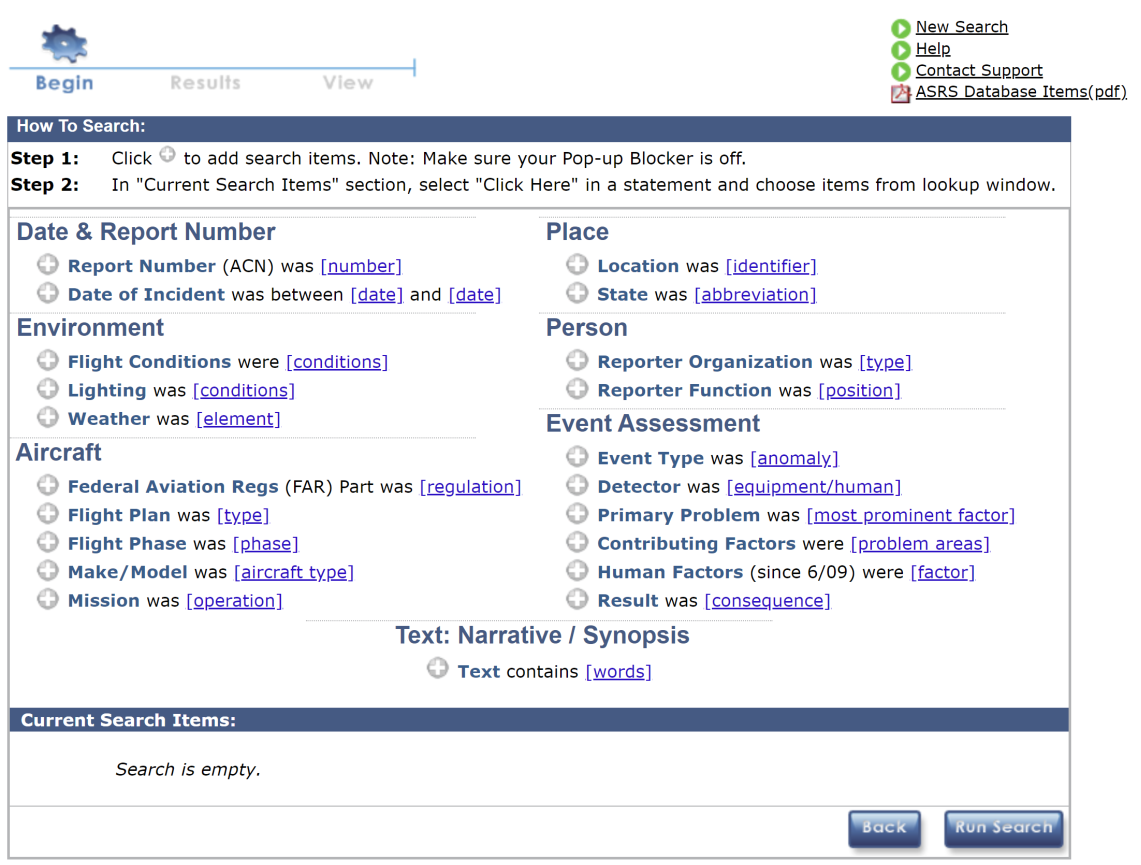
ASRS reports can be made up of information from seven categories: Date and Report Number, Environment, Aircraft, Place, Person, Event Assessment, and Text. Within each of these categories, several pieces of information can be found. While NASA reserves the right to remove information for the sake of deidentification, one category on its own cannot provide a clear representation of an event and needs other categories to fill in the information. Of the seven categories, there are two that provide most of the narrative information: Event Assessment and Text.

Using the ASRS

When searching for safety reports from the ASRS, there are a multitude of ways of finding reports. Out of all the categories, the user can click on one of the subcategories and input a value. As seen in Figure 3, there are many different ways to search for certain reports.

Figure 3

The User-Interface for the ASRS

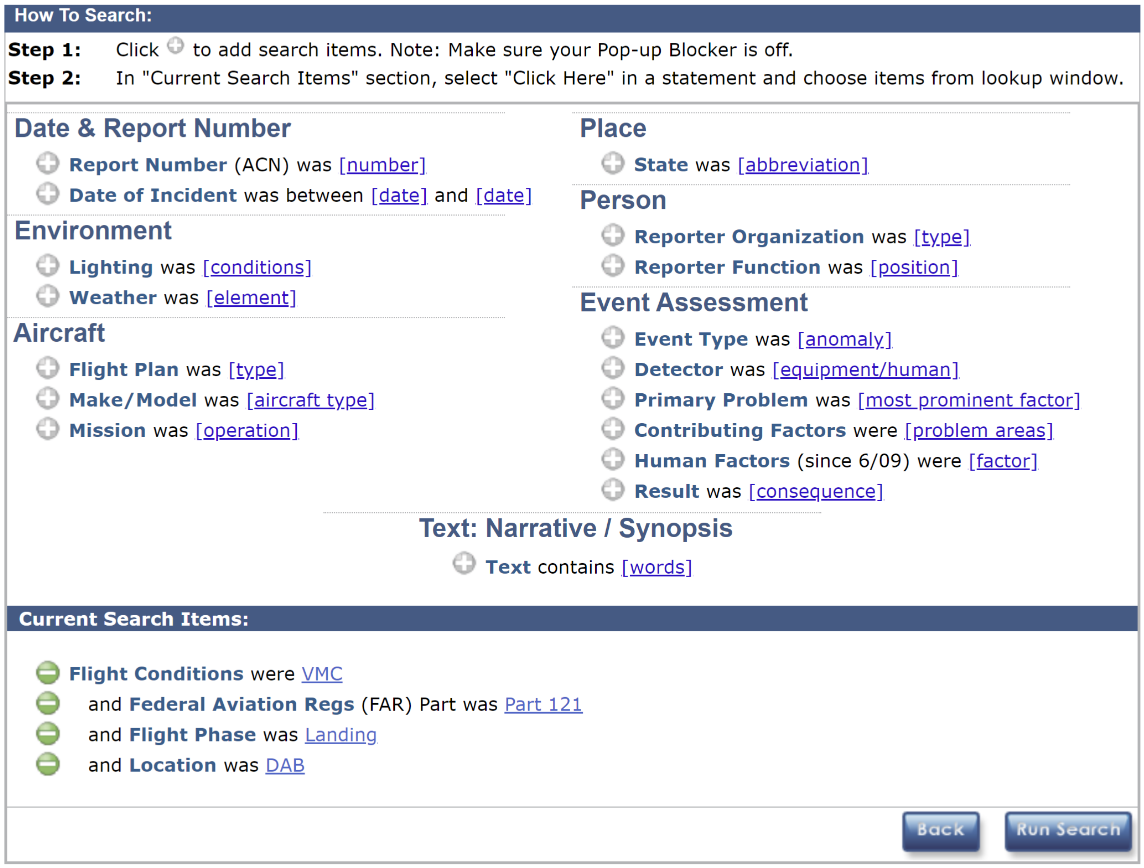


Note. From *ASRS Database Online*, by Aviation Safety Reporting System. https://akama.arc.nasa.gov/ASRSDBOnline/QueryWizard_Filter.aspx

Through the use of a combination of subcategories, a list of reports can be generated for the user. For example, if a search were to be conducted for Part 121-operated flights in Visual Meteorological Conditions (VMC) while landing at Daytona Beach International Airport (DAB), the search would look like Figure 4.

Figure 4

An example ASRS search



With this search, three results are generated, matching the parameters entered. While each of the three is different in their nature, the structure of the report is the same: information on the time and place followed by the people involved in the report. After that, an assessment of the event is followed by the narrative and synopsis. While not every report has information removed, NASA follows the practice of removing information that can be used to identify individuals involved in the reports.

As shown in Figure 5, a deidentified report can make it hard for someone to understand the whole picture. With the state, airport, and Air Traffic Control (ATC) information removed, understanding the environment in which this incident took place could be challenging.

Figure 5

A section of a deidentified ASRS report

Place

Locale Reference.Airport : ZZZ.Airport
State Reference : US

Environment

Weather Elements / Visibility : Rain

Aircraft

Reference : X
ATC / Advisory.Ground : ZZZ
Aircraft Operator : Air Carrier
Make Model Name : Medium Large Transport, Low Wing, 2 Turbojet Eng
Crew Size.Number Of Crew : 2
Operating Under FAR Part : Part 121
Flight Plan : IFR
Mission : Passenger
Flight Phase : Taxi

Note. This section comes from ASRS Report Number: 1877053

While this deidentification helps preserve the anonymity of the reporters, it can make some reports less valuable than others. One way to provide insight into the event without exposing who was involved with the incident would be to include an ADS-B source with each report.

Theoretical Framework

Based on the literature, understanding the complex task of taxiing allows pilots to evaluate the risk for any given situation. However, the lack of an understanding of any interaction between factors such as surface contamination and airport geometry leaves room for an increased risk during taxi operations. The attempt to understand these interactions helped guide the development of this study. Aviation safety reports can be useful in some scenarios; however, when information is withheld, it can be challenging to understand the whole picture.

Research Model

As defined by seeking an understanding of flight crew decision-making during taxi operations, for hypotheses one and two, an Analysis of Variance (ANOVA) is the appropriate statistical measure. The use of an ANOVA allows for the comparison of ground speed during different taxi situations, creating a range of normal taxi speeds while at the same time evaluating what affects the decision-making of a flight crew. The use of past incidents allows for an evaluation of how pilots can judge the conditions and how close they pilot their aircraft toward a dangerous situation.

Summary

The literature regarding airport geometry, abnormal taxi operations, and previous taxi models indicates that attempting to evaluate flight crew decision-making can provide an empirical way of evaluating flight crew decision-making. Furthermore, with the added information from ASRS reports, understanding why flight crews operate the way they do can be understood. The information coming directly from the flight crews can add a layer of information that is more beneficial than estimations of other factors. The methodology will be explained in the upcoming chapter, and how connecting ASRS reports to other data sources will contribute to a better understanding of flight crew decision-making.

Chapter III: Methodology

This study examined the significant differences between aircraft taxi speed and two different factors: taxiway intersection angle and taxiway surface contamination. Flights were selected from airports around the United States of America, and data was recorded on the groundspeed (DV), taxiway intersection angle, and surface contamination (IVs)

Upon collecting the flight data, the variables were analyzed for and assessed, as well as their effect on flight crew decision-making (groundspeed). An ANOVA was conducted to determine the variables' statistical significance. The following sections introduce the research methodology, flight selection process, data collection process, and strategy for hypothesis testing.

Research Method Selection

This study implemented quantitative research methods to investigate the relationship between multiple factors in taxi operations. Flight crew decision-making, the dependent variable (DV), was operationalized by aircraft ground taxi speed. The independent variables (IV), taxiway intersection angle and taxiway surface contamination, were evaluated for any effect on the dependent variable and an interaction between the two IVs.

Population/Sample

The population for this study consisted of Part 121 flight operations within the United States of America. The accessible population consisted of flights that contained valid ADS-B out signatures while taxiing at an airport.

Population and Sampling Frame

The accessible population was identified using two factors: aircraft operating at airports that have valid ADS-B readings and operations at airports that publish Field Condition (FICON) NOTAMs. Flights that were selected were intentionally limited to Part 121 commercial operations due to two main factors: data availability and the wide variety of airports with Part 121 operations.

Sampling Strategy

Convience sampling was used to collect the flights for analysis from airports around the country. The researcher identified flights based on the two independent variables, surface contamination, and taxiway angle. The surface contamination was verified through the use of FICON NOTAMs. Flights were then sorted into categories based on one turn during taxi operation and not used in any other group. In total, 88 flights from three airports, Minneapolis-St Paul Intl. Airport, Chicago O'Hare, and Hartsfield-Jackson Atlanta Intl. Airport. All flights contained valid ADS-B logs and allowed for an analysis of flight crew decision-making.

Data Collection Process

During the sampling process, the researcher identified potential airports around the country that could contain flights with usable ADS-B flight logs. Once flights were identified, data on an aircraft's position, speed, and heading were collected and stored for analysis.

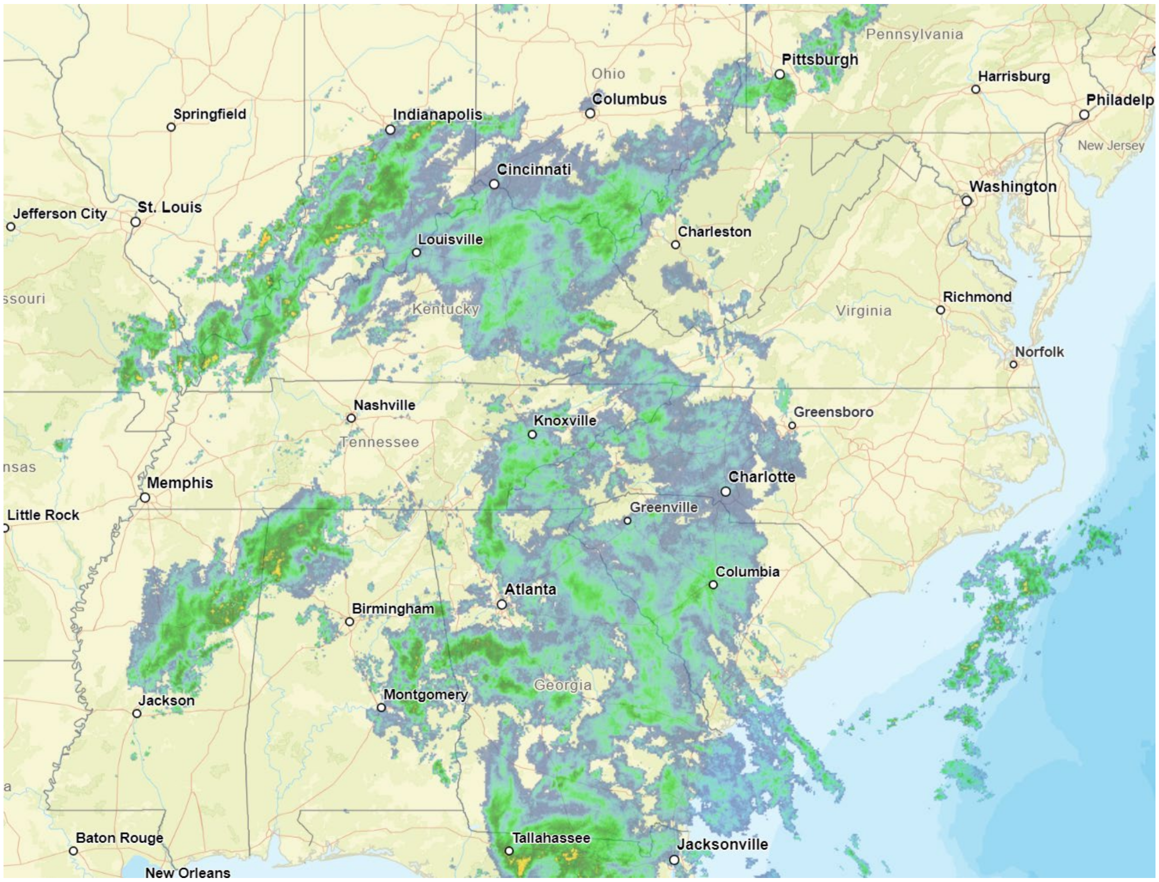
Design and Procedures

This study implemented a non-experimental design to investigate how surface conditions and taxiway angle impacted flight crew decision-making during taxi operations. A non-experimental design was chosen due to the reliance on observations of flight data rather than manipulating flights. The use of an ANOVA would allow for statistically significant differences to be found, indicating some of the factors that flight crews use to base their groundspeed on.

Airport Identification. In order for data to be collected on one of the independent variables, taxiway surface contamination, the researcher required that an airport have an active FICON NOTAM indicating the breaking conditions for an active runway or taxiway. In order to identify these airports, the researcher first consulted the weather radar from the National Weather Service (NWS). The researcher looked for returns from the radar that would indicate rain, snow, or any other precipitation, such as Figure 6 (National Weather Service, 2023).

Figure 6

The National Weather Service Radar



Note. The color of the return represents the strength of precipitation: Green – Light Rain, Yellow – Medium Rain, Red – Heavy Rain, and Pink – Snow. Image retrieved from *https://radar.weather.gov*

Once a potential airport was identified, the researcher used the FAA's NOTAM Search to check for a FICON NOTAM indicating the surface conditions at the airport (FAA, 2024a). If a FICON NOTAM was present, then flights from that airport could be categorized as wet operations. If there was no precipitation present or no NOTAM indicating wetness at an airport, it was assumed that the taxiway surface condition was dry.

Flightradar24 was chosen to be used by the researcher to download ADS-B reports. Flightradar24 has the largest ADS-B network in the world, with over 30,000 receivers worldwide (Flightradar24, 2024). The researcher located airports that had been identified as potential sources of flights and checked to see if there were flights with valid ADS-B track logs while taxiing. Once a flight was found to meet the criteria, a Comma-separated values (CSV) file was downloaded containing a flight's position, altitude, speed, and direction data. Each file contained entries that logged each parameter every 5-10 seconds.

The researcher identified a collection of entries in the flight log indicating a turn on the ground by comparing the GPS location to that of a taxiway intersection at the airport where the flight is located. Each flight's ground speed at turn entry, change in heading, and time to complete a turn were recorded into a master Microsoft Excel sheet. In the master sheet, demographic information on each flight (airline, aircraft make, airport, intersection) was collected, as well as all of the variables. Once all 88 flights had their data collected, the Excel file was converted into an International Business Machines (IBM) Statistical Product and Service Solutions (SPSS) Version 27 data file for hypothesis testing.

ADS-B from ASRS Reports. Deidentification of ASRS reports proved to be a challenge in identifying ADS-B data. Many times, reports would have their airport and location on the airport redacted. While there is no way of assuming the location, the partial date may provide a path toward the identification of ADS-B data. The researcher aimed to first identify the exact date that an ASRS report was about. The researcher combined part of the narrative information with the month to create a string of text that was entered into a search engine. If the event happened at a medium-sized airport, a local news station may have a story about the event. Sometimes, the report would contain a flight number, and other times, the only information was the airline.

If there were no news stories on the event, social media was also used to attempt to find the event. Social media presented a few issues. The first issue was misinformation. Many times, social media posts contain information that is directly opposite to what was recorded in the ASRS report. Additionally, many posts would be delayed by a day or two, inaccurately reporting the date of the event. Another issue was with ADS-B data availability. On the rare occasion that the researcher was able to identify an event, the ADS-B data was not available. Using the same ADS-B commercial service, Flightradar24, any flight older than three years would not have its ADS-B data saved.

Apparatus and Materials

The researcher used a computer to collect all data for this study. Flight data was collected using Flightradar24. ASRS reports were also collected from the FAA. For data analysis, Microsoft Excel was used to store all flight data together in one file, and IBM SPSS Version 27 was used to conduct hypothesis testing. The ASRS database was used to collect ASRS reports. Additionally, an ADS-B source is required for flight information. The computer was also used to calculate the ANOVA. The results of the ANOVA were analyzed using IBM’s Statistical Package for Social Sciences (SPSS).

Sources of the Data

All data collected was downloaded from secondary data sources. The researcher accessed three different databases to collect data: the FAA's NOTAM database, the ASRS database, and Flightradar24.

Ethical Consideration

One of the goals of this study was to connect ASRS reports to ADS-B data. The researcher did not attempt to identify any individuals involved but rather the flight that the report was written on. This study used data that are all accessible in the public domain, and an analysis of the Embry-Riddle Aeronautical University Institutional Review Board's Decision tree (see Appendix A) showed that no Institutional Review Board review was required.

Variables and Scales

The ratio-level dependent variable was efficient taxi operation, operationalized by ground speed in knots. This study analyzed two independent variables: intersection angle (ratio) and surface contamination (nominal).

Data Analysis Approach

The main goal of this study was to investigate flight crew decision-making during taxi operations, and thus, an ANOVA was chosen. The two independent variables were converted into categorical data and allowed for the data to be split into four groups based on the surface contamination level (dry and wet) and the intersection angle (30-60 degrees and 75-105 degrees).

Reliability Assessment Method

As this study relied on secondary data, there was no internal reliability assessment; however, the reliability of the data sources was evaluated. As most of the data came from government agencies or Flightradar24, it is assumed they would be reliable. For the ADS-B data, a reliable signal was determined by valid responses for a flight while on the ground. The researcher was responsible for determining the quality of the ADS-B data.

Validity Assessment Method

As the study used secondary data, the validity of the data comes from the data sources. It was assumed that all ASRS reports were entered correctly and that the ADS-B data that was collected was recorded accurately and not manipulated in any way.

Summary

This chapter describes the process that was used to conduct this study. Flights were identified and used to evaluate flight crew decision-making. The next chapter will cover the results of each independent variable and how they influence the dependent variable.

Chapter IV: Results

This chapter presents the results of the study. The results include two main sections: descriptive statistics and hypothesis testing.

Two-way ANOVA Assumptions

The data used in this study was able to meet two of the three assumptions for a two-way ANOVA. The first assumption that was tested was to check for any outliers. From a visual inspection of a boxplot, there were no outliers greater than three box lengths from the edge of a box in a boxplot. The second assumption was to check for normality in each group. The data was normally distributed in all groups, as assessed by Shapiro-Wilk's test ($p > .05$). The final assumption was that of homogeneity. Levene's test for equality of variance indicated that there was a violation of homogeneity ($p = .012$). However, the two-way ANOVA is rather robust to heterogeneity if the group sample sizes are equal, there is normality, and the ratio of the largest group variance to the smallest group variance is not too large (Jaccard, 1998). Thus, the two-way ANOVA was conducted.

Descriptive Statistics

The means and standard deviation based on the intersection angle group and surface conditions are shown in Table 1. The taxiway angle (IV) was split into two groups, with the groups being a 30-60-degree turn and a 75-105-degree turn. The distribution of the raw angles for determining the taxiway groups can be found in Figures 7 and 8. The distribution of the four groups can be found in Figures 9-12

Figure 7

Taxiway Angles for All of Group One

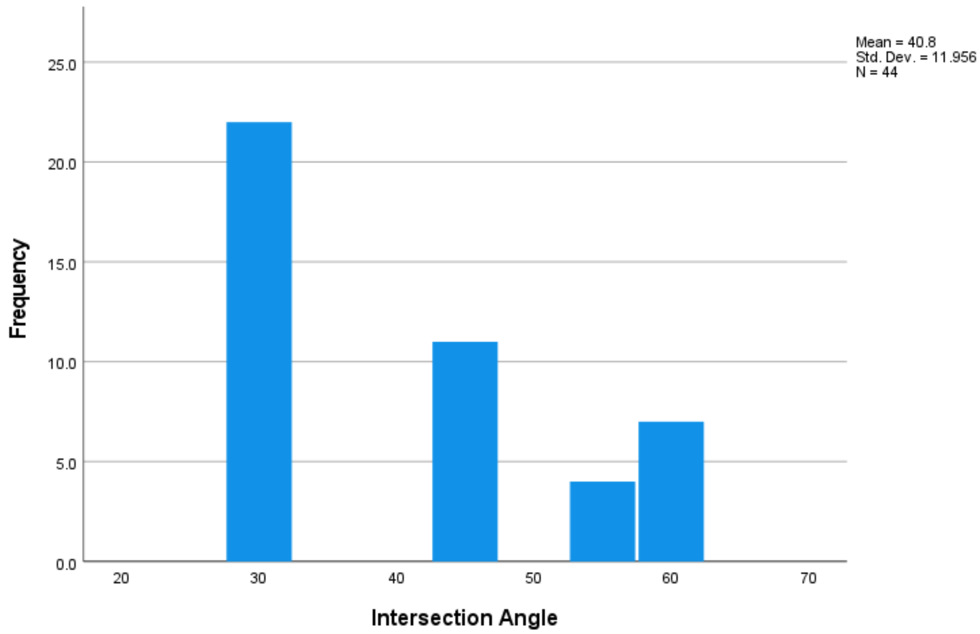


Figure 8

Taxiway Angles for All of Group Two

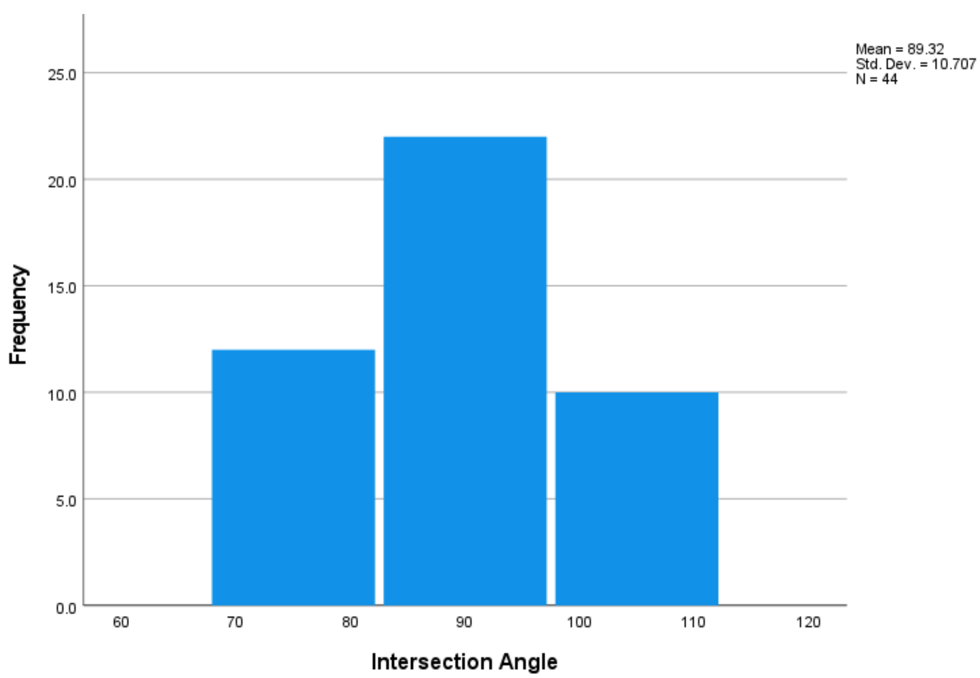


Table 1

Mean and Standard Deviation of Groundspeed

Group	Dry	Wet
Taxiway Group		
Group 1 (30-60 degrees)	$M = 18.77$, $SD = 4.628$	$M = 14.68$, $SD = 3.242$
Group 2 (75-105 degrees)	$M = 15.45$, $SD = 2.324$	$M = 14.32$, $SD = 2.626$

Figure 9

Group 1 (Taxiway Group 1 and Dry Conditions) Distribution

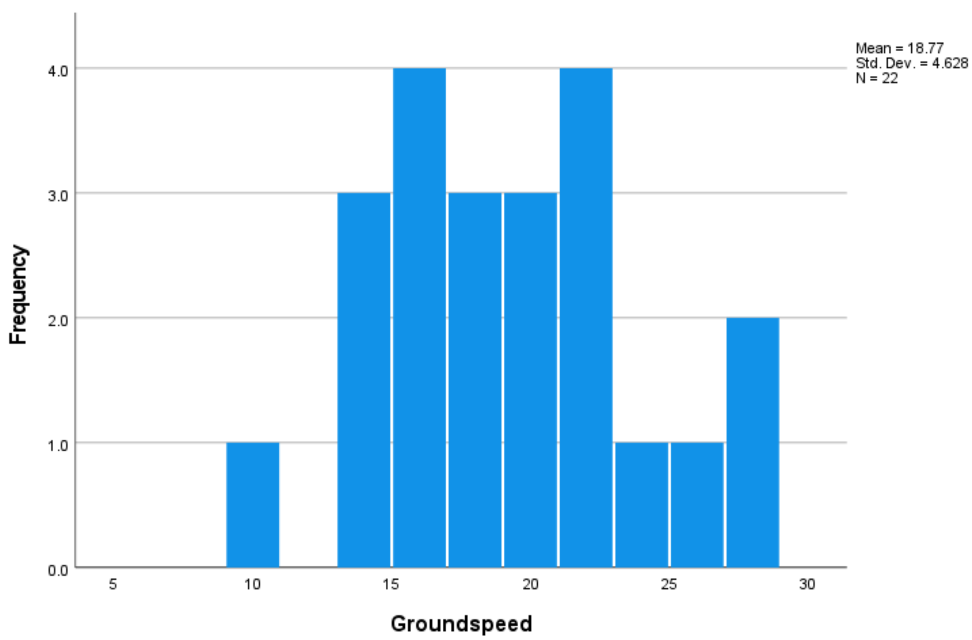


Figure 10

Group 2 (Taxiway Group 2 and Dry Conditions) Distribution

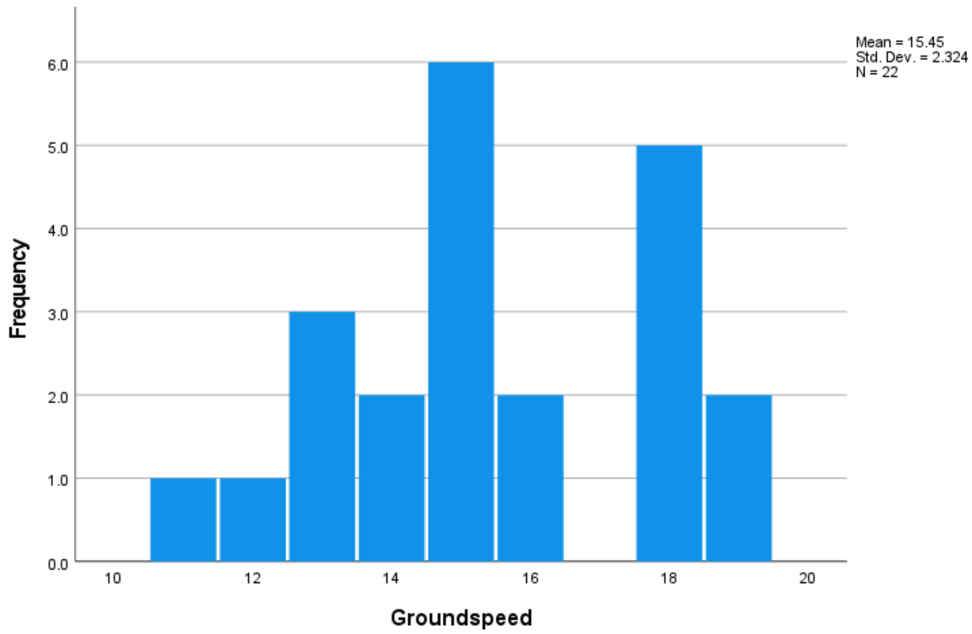


Figure 11

Group 3 (Taxiway Group 1 and Wet Conditions) Distribution

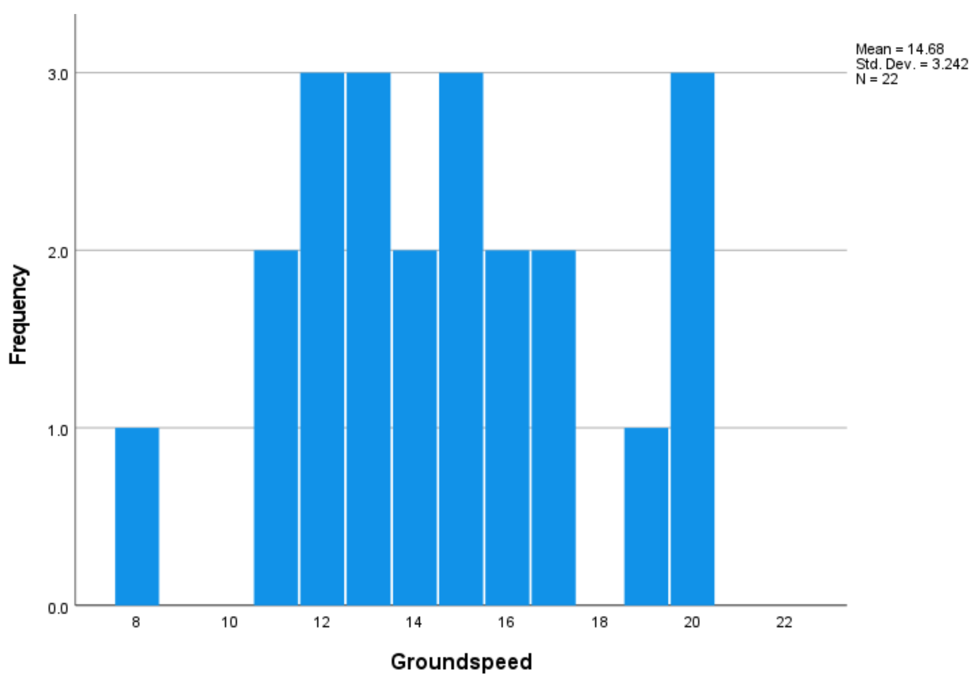
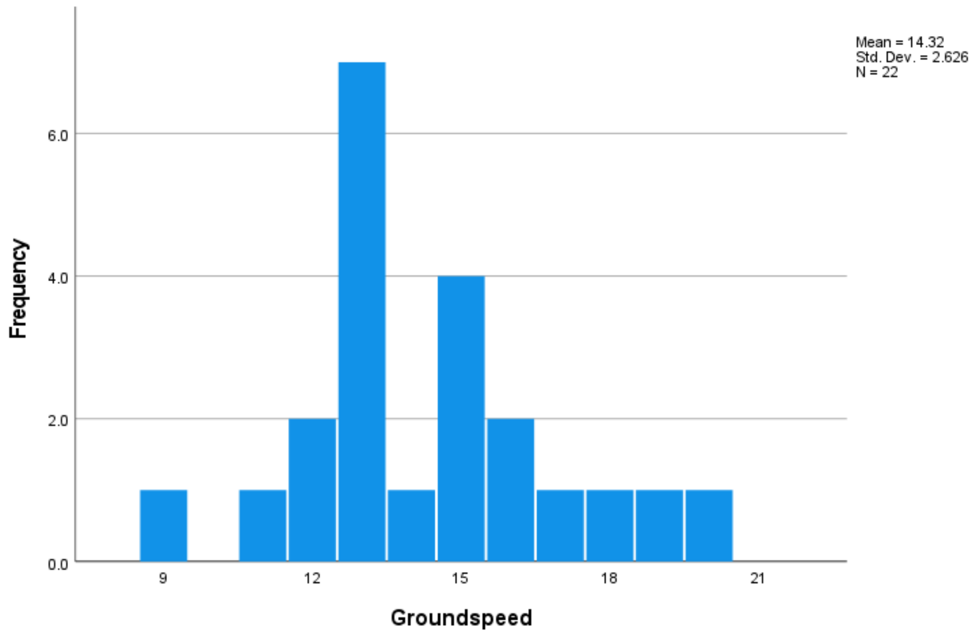


Figure 12

Group 4 (Taxiway Group 2 and Wet Conditions) Distribution



Hypothesis Testing Results

Three hypotheses were derived from two research questions that were evaluated in this study.

$H_0 1$: There is no statistically significant difference in flight crew decision-making during taxi operations due to differences in taxiway intersection angle.

$H_0 3$: There is no statistically significant difference in flight crew decision-making during taxi operations due to differences in surface contamination.

$H_0 3$: The information in an ASRS report cannot be used to identify the ADS-B records for that report.

Two-way ANOVA Results

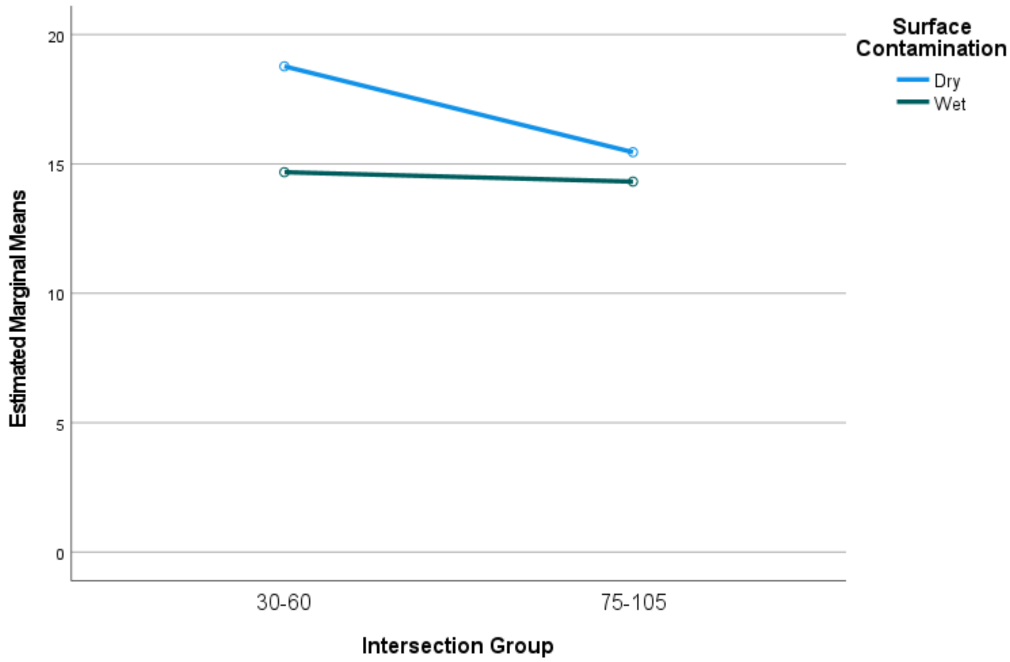
Upon analysis for an interaction between surface contamination and taxiway angle, there was a statistically significant interaction for groundspeed, $F(1, 84) = 4.342$, $p = .040$, partial $\eta^2 = .049$. The ANOVA was then analyzed for simple main effects. The first main effect examined was surface contamination. There was a statistically significant difference in groundspeed based on surface contamination, $F(1, 84) = 13.591$, $p < .001$, $\eta^2 = .139$, and thus null hypothesis H_01 was rejected. The second main effect examined was the taxiway angle group. There was a statistically significant difference in groundspeed due to taxiway angle, $F(1, 84) = 6.721$, $p = .011$, $\eta^2 = .074$, and this null hypothesis H_02 was rejected.

The Interaction Effect

For intersection angles that were 30-60 degrees, mean groundspeed was 3.318 (95% CI, 1.324 to 5.312) knots higher in dry conditions than wet conditions (see Figure 13), $F(1, 84) = 10.953$, $p = .001$, partial $\eta^2 = .115$ and thus null hypothesis one is rejected. For intersection angles that are 75-105 degrees, there was no significant difference between dry and wet conditions ($p = .260$). In wet conditions, there was no statistically significant difference in groundspeed amongst taxiway angles, $F(1, 84) = 0.432$, $p = .718$.

Figure 13

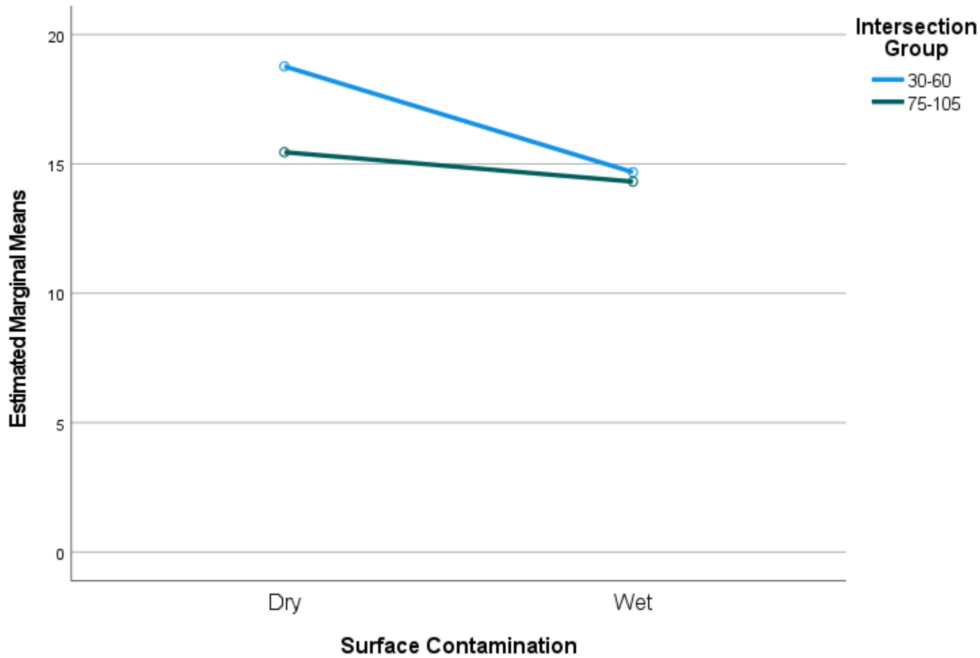
Estimated Marginal Means of Grounspeed from Intersection Group



The evaluation of surface contamination indicated that for dry conditions, taxiway angles 30-60 degrees had ground speeds 4.091 (95% CI, 2.097 to 6.085) knots faster than 75-105 degree intersections (see Figure 14). The ANOVA for dry conditions was statistically significant, $F(1, 84) = 27.017$, $p < .001$, $\eta^2 = .300$, and thus null hypothesis two was rejected.

Figure 14

Estimated Marginal Means of Grounspeed from Surface Contamination



ASRS and ADS-B

The barriers presented in Chapter 3 ultimately limited the researcher from being able to access any ASRS report event's ADS-B data. Utilizing the process laid out in Chapter 3, it was hard to find a record for any event greater than 6-12 months old. Being unable to access the specific date of an event limited the ability to accurately search for a flight number to access the ADS-B data. For the purposes of this study, $H_0 3$ will be retained.

However, the researcher was able to find some ADS-B records for significant events without using ASRS in their entirety. A simple search using a search engine could lead to news articles about events containing flight numbers if they happened recently.

The same limitations apply to using news articles as before; information can be wrong concerning the aircraft type, event date, and flight number. Care should be taken when using non-official sources to identify flights.

Summary

This chapter presented the results of analyses used in this study in this study. The ANOVAs indicated that null hypotheses one and two should be rejected; both the surface conditions and the taxiway intersection angle impacted the groundspeed, entering the turn. Additionally, the researcher was unable to connect ADS-B with the ASRS system. Ultimately, the deidentification, coupled with the lack of other supporting evidence, did not allow for a successful connection to be established between the two systems. The following chapter will discuss the results and the conclusions, limitations, and recommendations for the target population and for future research.

Chapter V: Discussion, Conclusions, and Recommendations

This study investigated flight crew decision-making through an analysis of ground speed entering a turn during taxi operations. The hypothesis testing results presented in chapter four are discussed to explain the significant differences. Further, this chapter describes recommendations for future research and the possibility of a connection between the ASRS database and an ADS-B source.

Discussion

The results showed that groundspeed was significantly different based on both the surface contamination and the taxiway angle. These findings provide unique insights into pilot decision-making and future research opportunities using ADS-B and the methodology from this study.

Surface Conditions and Taxiway Intersection Angle

Surface contamination was found to be a significant factor in flight crew decision-making. This follows common sense and recommendations to slow down when the conditions differ from a dry surface (Havarikommissionen, n.d.). What was unique about the surface conditions was the range between the two groups, wet and dry. In dry conditions, the flights analyzed had a wide range across all taxiway angles, whereas the flights for wet surface conditions had a relatively small range.

These findings present a unique situation for flight crew decision-making. The Airbus A320 family Flight Crew Training Manual states that for turns of 90 degrees or more, the aircraft should be slowed down to 10 knots or slower (AIBD, n.d.). For wet operations, the mean ground speed entering a turn was higher than 10 knots by at least 4 knots for all taxiway intersection angles. Dry conditions proved to contain even higher ground speed averages, with 75-105-degree turns averaging 15.5 knots and 30-60 degrees at 18.77 knots. While not every aircraft sampled was part of the Airbus A320 family, many similar-sized aircraft were used in this study. This makes it appear that there could be some guidance that is provided to flight crews that is different from Airbus's recommendations.

Taxiway intersection angle was also found to be a factor in dry taxi operations. During dry operations, the greater the angle of the taxiway, the slower the aircraft entered the turn. While this follows common sense, there is still a difference between the Airbus recommendation and the observed ground speeds in this study.

Conclusions

The two-way ANOVA conducted in this study indicated that the combined interaction between surface contamination and taxiway intersection angle led to statistically significant differences in the ground speed entering a turn during taxi operations. The flights included in this study were observed to taxi between 18-23 knots in dry conditions and 10-15 knots in wet conditions. While ADS-B was used to observe these differences, the researcher was unable to connect ADS-B to the ASRS system in an attempt to understand "why" flight crews make these decisions.

ASRS has potential beyond how it is currently used. Flight crew-authored reports allow for direct access to information and ideas from the flight deck within an anonymous setting. The current system of deidentifying flight information can remove the context for the reports coming directly from the flight deck. A combined system in which the reports contain the narrative information while also having an ADS-B file would improve the ASRS system.

Theoretical Contributions

This study showed that it was possible to use a commercial ADS-B source to analyze flight crew decision-making during taxi operations. However, the ASRS system is in need of an upgrade to include flight data. ASRS provides "the why" for normal operations, events, and incidents. The inclusion of these data would provide the necessary context that the current ASRS system removes in the deidentification process. As ADS-B contains the flight number, position, speed, and altitude, the removal of the flight number when attached to an ASRS report could help preserve that anonymity.

Practical Contributions

This study rejected null hypotheses one and two and retained null hypothesis three. The analysis of flight crew decision-making indicated that the flight crew's choice in ground speed entering a turn is impacted by both the taxiway angle and the surface contamination. Flight crews should slow down for taxiway intersections as the intersection angle increases and as the surface contamination worsens. Airlines could use the methodology presented in this study to compare their internal performance data to the data of other airlines looking for differences in taxi operations and provide flight crews with additional guidance based on the findings.

Limitations of the Findings

One purpose of this study was to connect ASRS reports with their flight data; however, as previously discussed, ADS-B data was not able to be identified for ASRS reports. Additionally, this study only focused on Part 121 operations inside of the United States. Utilizing the data in this study outside of the United States has potential, but caution should be observed as the regulations for airports and commercial operations are different from those of the United States. The results from this study should not be used to make decisions in general aviation taxi operations due to the differences in aircraft and taxi operations.

Recommendations

While ADS-B data could not be connected to ASRS reports at this time, the narrative information contained in ASRS reports is extremely beneficial for understanding why a flight crew is acting a certain way in the flight deck during taxi operations. NASA should be required to attach an ADS-B record to each report by downloading the data through a commercial provider, such as this study did.

If NASA were to remove the flight number, leaving only the position, speed, altitude, and heading data along with the current practice of only providing the month and year of a report, that would help ensure the confidentiality of the reports. Hiding the identification of flight crews, combined with the current ASRS immunity policies, provides the air transportation industry with a more open setting for evaluating flight crew decision-making.

The findings of this study should be considered by both Part 121 operations and policymakers, as this study could be used to influence how taxi operations are conducted. Currently, airlines may not have policies for a maximum, but the autonomous Flight Operational Quality Assurance (FOQA) program may highlight taxi speeds around 30 knots (Anonymous, personal communication, March 2024). Utilizing a combined ASRS and ADS-B system could help airlines and policymakers with improvements in taxi operations.

Recommendations for Future Research

This study provides a baseline for evaluating flight crew decision-making during taxi operations at airports in the United States. Additional research should be conducted for different countries around the world to get a better picture of the global commercial aviation industry. As the aviation industry becomes more globally connected, transcontinental operations become more frequent, with a growing number of regulations to follow in each country. Analyzing the differences between countries and their operators could provide more insight into better rule-making for taxi operations. An analysis of flight crew performance to detect differences could be expanded into other aviation operations, including Uncrewed Aircraft Systems, Air Traffic Control, and ground services.

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Appendix A

Institutional Review Board Flow Chart