Runway Incursions: A Case Study Analysis

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Abstract

Utilizing publically-available information gathered from government resources, a case study analysis of runway incursion data endeavored to determine the correlation between the reported incursions that occurred at American airports between fiscal years 2009 and 2011 and the meteorological conditions, times of day, and presence of an air traffic control tower. With runway incursions long-plaguing the safety of United States aviators, their passengers, and aviation personnel, continued research aimed at refining the body of knowledge underpinning incursions coupled with ongoing prevention efforts aspire to diminish the annual incidence of incursions, increase safety, and save lives. In accordance with this mission, mining the National Transportation Safety Board's (NTSB) and National Aeronautics and Space Administration's (NASA) runway incursion databases and analyzing the resulting data with the Pearson correlation indicated a higher likelihood of incursions amid clear weather, during the daylight hours, and at airports with an air traffic control tower.

Introduction

As a result of the continued, multi-faceted threat that runway incursions pose to the safety of many aviation users despite longstanding efforts to diminish their incidence, a case study analysis of incursion data archived within the NTSB's and NASA's databases sought to determine the positive or negative correlations between incursions and several situational factors. With 2,871 runway incursions compromising the safety of pilots, passengers, and airport personnel between fiscal years 2009 and 2011, answering the following questions aimed to refine the aviation industry's collective understanding of the conditions that were more favorable for incursions (Federal Aviation Administration [FAA], 2013b).

1. What are the correlations between meteorological conditions and the reported runway

incursions that occurred between October of 2008 and September of 2011?

2. What are the correlations between times of day and the reported runway incursions that occurred between October of 2008 and September of 2011?
3. What is the correlation between air traffic control towers and the reported runway incursions that occurred between October of 2008 and September of 2011?

Through adherence to such guiding questions, a case study analysis of publically-available, government resources focused on runway incursions aspired to improve aviation safety by furthering regulators', instructors', aviators', and airport operators' awareness of the meteorological and environmental conditions in which incursions were more likely to occur.

Literature Review

Within the twelve-month fiscal year spanning October of 2010 and September of 2011, 954 runway incursions endangered the 50,739,762 aircraft operations that air traffic controllers recorded within the U.S. during the same period, and despite efforts to curb the incidence of incursions, the 2011 rate of 18.8 incursions per 1,000,000 aircraft operations marked a 0.8-point increase over 2009 (FAA, 2013a; FAA, 2013b; FAA, n.d.). Jointly defined by the International Civil Aviation Organization (ICAO) and the Federal Aviation Administration (FAA) as "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle[,] or person on the protected area of a surface designated for the landing and take-off of aircraft" (FAA, 2010b, p. 2), runway incursions threaten the safety of aircraft pilots, their passengers, and aviation personnel. In spite of the aviation industry's collective initiatives aimed at preventing runway incursions, such as the NTSB's inclusion of incursion reduction on its aviation safety Most Wanted List since the list's inaugural publication in 1990, an average of three incursions continue to imperil America's aviation system daily (FAA, 2012; NTSB, 2007). Examining the

FAA's causal classification of runway incursions, exploring their severity categorization of incursions, and studying the research-identified factors underpinning incursions affords a comprehensive understanding of incursions that offers the opportunity to diminish their occurrence through education (FAA, 2009).

Constructing a foundation of knowledge upon which to build an understanding of runway incursions and reduce their impact on aviation safety, the FAA classifies incursions as operational error, pilot deviation, or vehicle or pedestrian deviation according to the aviation stakeholder whose actions resulted most significantly in an incursion (Air Line Pilots Association, International [ALPA], 2007; FAA, 2009). The consequence of an air traffic controller's clearing an aircraft for takeoff or landing on a closed runway or instructing an aircraft to maneuver such that regulated separation with other aircraft, ground vehicles, or aviation personnel is lost, operational error attributes responsibility for such incursions to air traffic controllers. Similarly, pilot deviation apportions a majority of the responsibility for a runway incursion to pilots when an incursion results from a pilot's violation of a Federal Aviation Regulation (FAR). Correspondingly, when individuals on foot or in a vehicle, as well as aircraft under the command of personnel other than pilots, enter an airport's movement area without the requisite permission of an air traffic controller, the FAA defines the resulting incursion as a vehicle or pedestrian deviation (FAA, 2009). Collectively, operational error, pilot deviation, and vehicle or pedestrian deviation not only comprise the FAA's classification of runway-incursion causation, but also serve as the starting line in the FAA's pursuit of information that will facilitate an enduring reduction in the annual rate of incursions.

Although the FAA's delineation of causal classifications is imperative in the construction of a firm foundation in knowledge of runway incursions, such prose translates into meaningful reductions in the incidence of incursions only when paired with corresponding data. Accordingly, during fiscal year 2009, operational error accounted for 16% of runway incursions, pilot deviation resulted in 63% of incursions, and vehicle or pedestrian deviation preceded 21% of incursions. Moreover, among the 63% of runway incursions that were prompted by pilot deviation, 77% were caused by general aviation pilots, as compared to 23% by commercial pilots (FAA, 2010a). Without minimizing the threat posed by runway incursions that result from air traffic controllers' operational errors and aviation personnel's vehicle or pedestrian deviations, general aviation pilots' deviations simultaneously represent the most significant source of incursions and the greatest opportunity for reducing the annual rate of incursions within the U.S.

Building upon the foundation of causation articulation, the FAA's similar categorization of runway incursions' severity serves as the cornerstone of incursion understanding and prevention. Accounting for the reaction time provided, the severity of corrective action required, the environmental setting, and both the speed of and distance between an aircraft and conflicting aircraft, equipment, or individual, the FAA's categorization of the severity of runway incursions ranges from Category A to Category D in decreasing order of severity (FAA, 2009). Specifically, while the degradation of separation to a level at which a collision scarcely is avoided constitutes a Category A runway incursion, a Category B incursion results when separation is reduced such that a collision is probable without prompt action. Whereas a Category C incursion is the outcome of separation reduction with sufficient time and distance for collision prevention, a Category D incursion arises when the definition of an incursion is met despite the diminished risk of collision (ALPA, 2007; FAA, 2009). Akin to the composition of causation classifications, defining severity categorizations only prevents runway incursions and improves aviation safety through the application of corresponding data. To this end, 1% of the runway incursions that were documented during fiscal year 2009 were Category A incursions, 0.32% were Category B, 36% were Category C, and 63% were Category D (FAA, 2010a). Together, defining and quantifying both the severity categorizations and causation classifications of runway incursions enables the FAA to target its limited resources at the gravest threats posed by incursions.

Supplementing the FAA's data-driven efforts to understand and prevent runway incursions, published research examining the interactions between incursions and human characteristics, meteorological conditions, and airport environments offers complimentary insights into sustainable, long-term strategies for combating incursions. Utilizing Taiwanese regulatory administrators', accident investigators', and commercial aviators' questionnaire responses to study the relationships between 56 human factors and runway incursions in Taiwan, Chang and Wong (2012) concluded that, while weather was a risk factor associated with incursions, the absence of an air traffic control tower was not a prominent factor. Additionally, Rogerson and Lambert (2012) included the annual average of days with temperatures below 32 °F, above 90 °F, and with rain, as well as the annual snowfall and difference in the hours of sunlight on the summer and winter solstices, in their case study-application of the multi-factor elicitation method for risk assessment to runway incursions. Finally, noting that the "time of day (day vs. night) and meteorological conditions (VMC [visual meteorological conditions] vs. IMC [instrument meteorological conditions]) have all been shown to influence aviation accidents when examined from a flight deck perspective" (p. 1), Pape, Wiegmann, and Shappell (2001) investigated the 69 incidents and 110 accidents that occurred between 1985 and 1997 in which the NTSB cited air traffic controller error. Hypothesizing that such "factors may…likely affect ATC [air traffic control]-related accidents as well" (Pape, Wiegmann, & Shappell, 2001, p. 1), they concluded that, while 65% and 71% of incidents and accidents occurred during the daylight and in VMC, respectively, a greater percentage of accidents than incidents occurred at night and in IMC, which warrants a similar study of runway incursions.

Together, the FAA's and private researchers' comprehensive investigations of the diversity of factors underpinning runway incursions furnishes regulators, controllers, aviators, and airport operators with the information requisite for conceiving, implementing, and executing long-term, sustainable initiatives designed to improve aviation safety through a reduction in incursions. Whereas the FAA has targeted its prevention efforts at educating aviation personnel through the assembly, analysis, and dissemination of incursion data, private researchers have focused on diminishing the incidence of incursions through an exhaustive analysis of the human, meteorological, and environmental factors accompanying incursions. Collectively, such public and private research efforts offer the aviation community the specific information that they have sought in their enduring mission to curb the incidence of runway incursions within America for the safety of all aviation personnel and the passengers who depend upon them.

Methodology

Designed as case study research mining the NTSB's Aviation Accident Database and NASA's Aviation Safety Reporting System (ASRS) Database, this case study analysis of runway incursion data relied not on participants, but on the information reported by aviation investigators and users. Accordingly, such research focused on the reported runway incursions that occurred within the U.S. between October of 2008 and September of 2011 because of the FAA's adherence to the October-to-September fiscal year, the FAA's fiscal-year-2008-adoption of the ICAO definition of an incursion, the innumerability of reported incursions, and the relevant timeliness of the reports filed between fiscal years 2009 and 2011 (FAA, 2010b). With such defined parameters, the case study construct not only permitted the recording of the meteorological conditions, times of day, and presence of an air traffic control tower for the reported runway incursions, but also presented the foundational opportunity to learn what the data were indicating through a preliminary, correlational analysis.

Defined by Salkind (2012) as "an index of the relationship between variables" (p. 396), and recognized as "the most frequently used measure of relationships" (Salkind, 2012, p. 204), the Pearson product moment correlation identifies as positive or negative the relationship between two variables. While a positive correlation is signified by the variables' increasing or decreasing together, whereas a negative correlation is indicated by the variables' increasing or decreasing conversely, neither a positive correlation, nor a negative correlation equates causation (Salkind, 2012). Seeking to explore beyond the data and answer its guiding questions through the independent analysis of the data assembled from the NTSB and NASA, the study employed the Pearson correlation to determine the relationships between runway incursions and meteorological conditions, times of day, and presence of an air traffic control tower.

Results and Discussion

Independently gathering and examining the runway incursion data archived by the NTSB and NASA, both datasets portrayed a higher incidence of runway incursions during visual weather conditions, during the daylight hours, and at airports with an air traffic control tower. Specifically, the NTSB documented eight runway incursions that occurred during VMC and one incursion that transpired during IMC, while NASA totaled 228 incursions that occurred during VMC and 15 incursions that transpired during IMC. Additionally, whereas the NTSB registered seven incursions that happened between the daylight hours of 0601 hours and 1800 hours and two incursions that took place between the nighttime hours of 1801 hours and 0600 hours, NASA similarly counted 192 incursions that happened between 0601 hours and 1800 hours and 51 incursions that took place between 1801 hours and 0600 hours. Finally, in comparison to the NTSB's investigation of eight incursions at airports with an air traffic control tower and one incursion at an airport without a control tower, NASA logged reports of 198 incursions that occurred at airports with a control tower and 45 incursions that happened at airports without a control tower (NASA, n.d.; NTSB, n.d.). As evidenced within Tables 1 and 2, a higher number of the reported runway incursions between fiscal years 2009 and 2011 occurred during VMC, between 0601 hours and 1800 hours, and at airports with an air traffic control tower, which decries the essentiality of aircraft operators' and airport personnel's elevated situational awareness within such operating environments.

Table 1: NTSB Runway Incursion Data

	FY 2009	FY 2010	FY 2011	Total
Meteorological Condition: VMC	5	2	1	8
Meteorological Condition: IMC	0	0	1	1
Time of Day: 0001-0600	0	0	0	0
Time of Day: 0601-1200	3	1	0	4
Time of Day: 1201-1800	2	0	1	3
Time of Day: 1801-2400	0	1	1	2
Air Traffic Control Tower: No	1	0	0	1
Air Traffic Control Tower: Yes	4	2	2	8

Table 2: NASA Runway Incursion Data

	FY 2009	FY 2010	FY 2011	Total
Meteorological Condition: VMC	91	73	64	228
Meteorological Condition: IMC	9	4	2	15
Time of Day: 0001-0600	2	11	6	19
Time of Day: 0601-1200	30	17	24	71
Time of Day: 1201-1800	48	38	35	121
Time of Day: 1801-2400	20	11	1	32
Air Traffic Control Tower: No	20	11	14	45
Air Traffic Control Tower: Yes	80	66	52	198

Despite the seemingly logical assumption that more runway incursions occurred during the inherently reduced visibility accompanying operation during IMC, within the hours of darkness between 1801 hours and 0600 hours, and at airports without the watchful guidance of an air traffic control tower, the NTSB's and NASA's raw data conveyed that the opposite was true. Considering many aviators' operating characteristics, however, the data's portrayal of a higher incidence of runway incursions during VMC, between 0601 hours and 1800 hours, and at airports with an air traffic control tower may be explained by the greater number of operations that occurred during clear weather, in the daylight, and at airports with enough operations to warrant a control tower. With regulatory and equipment limitations often precluding general aviation operators' flight outside of visual, daylight conditions, and given commercial operators' schedules that favor the daytime hours in which their customers are active, the data's elevated number of runway incursions during visual weather and daylight hours may correspond to an elevated number of operations.

Conversely, the data's reflection of fewer incidences of runway incursions during IMC, between 1801 hours and 0600 hours, and at airports without an air traffic control tower may have been the result of the diminished number of operations that occurred during poor weather, in the dark of the night, and at airports with too few operations to necessitate a control tower. Although the increased number of incursions reported at airports with a control tower may be explained by the greater volume of traffic and number of runways at such airports, the FAA's fiscal-year-2008-switch to ICAO's definition of an incursion may have confused operators and resulted in their failure to report incursions at airports without a control tower (FAA, 2010b). Still, as evidenced purely by the NTSB's and NASA's data, more incidences of runway incursions occurred during the periods when and at the airports where more aircraft operations were likely to have occurred.

Analyzing the raw data with IBM Statistical Product and Service Solutions' (SPSS) Pearson correlation function, study-specific indications were revealed regarding the correlations between the reported runway incursions and the accompanying meteorological conditions, times of day, and presence or absence of an air traffic control tower (Hall, 2009). As evidenced within Table 3, the NTSB data's output suggested that IMC and 1801 hours through 2400 hours were correlated negatively with the reported incursions, and they further conveyed an incalculable correlation between 0001 hours through 0600 hours and the reported incursions because of the absence of any incursions documented between those hours. On the other hand, the NTSB data's output indicated positive correlations between the reported incursions and VMC, 0601 hours through 1200 hours, 1201 hours through 1800 hours, and both the presence and absence of an air traffic control tower. Similarly communicated within Table 3, the NASA data's output articulated a negative correlation between 0001 hours through 0600 hours and the reported incursions, but the output suggested positive correlations between the reported incursions and VMC, IMC, 0601 hours through 1200 hours, 1201 hours through 1800 hours, 1801 hours through 2400 hours, and the presence and absence of a control tower. Applying the Pearson correlation to the data assembled from the NTSB and NASA, a majority positive and minority negative correlations were identified, which satisfied the guiding questions' pursuit of the relationships between the reported runway incursions and the meteorological conditions, times of day, and presence of an air traffic control tower.

Complimenting and contradicting the raw data and its unanimous clarity, the Pearson correlation's varied results not only indicated less conclusiveness in the relationships between the reported runway incursions and the dissimilar variables considered, but also underscored the enduring complexity of understanding and reducing incursions. Akin to the original data, both

Table 3: NTSB and NASA Correlations

		Total NTSB Reports	Total NASA Reports
Meteorological Condition: VMC	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	.971 .154 3	1.000 .007 3
Meteorological Condition: IMC	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	-.500 .667 3	.999 .026 3
Time of Day: 0001-0600	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	.* . 3	-.614 .579 3
Time of Day: 0601-1200	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	.945 .212 3	.629 .567 3
Time of Day: 1201-1800	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	.866 .333 3	.995 .064 3
Time of Day: 1801-2400	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	-1.000 .000 3	.973 .147 3
Air Traffic Control Tower: No	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	1.000 .000 3	.792 .418 3
Air Traffic Control Tower: Yes	Pearson Correlation (r) 2-Tailed Significance (p) Sample Size (N)	1.000 .000 3	.980 .128 3

* No data from which to calculate the Pearson correlation (How2stats, 2011)

outputs suggested that incursions may increase during VMC, between 0601 hours and 1800 hours, and at airports with an air traffic control tower, which, as before, may be explained by the greater volume of aircraft operations that occurred during clear weather, during the daylight hours, and at airports with a control tower. Further reflecting the raw data, the NTSB data's output advised that incursions may decrease during IMC and between 1801 hours and 2400 hours, and the NASA data's output proposed that incursions may decrease between 0001 hours and 0600 hours (Salkind, 2012). Collectively, these indications may be the result of the diminished volume of aircraft operations that occurred during poor weather and under the cover darkness.

Unlike the raw data, however, both outputs also conveyed that incursions may increase at airports without an air traffic control tower, which may be the product of such airports' sole reliance on pilots and vehicle operators to communicate their intentions and location diligently and accurately in order to see and avoid conflicts between aircraft and vehicles. Moreover, in contrast with the raw data, the output from NASA's data implied that incursions may increase during IMC and between 1801 hours and 2400 hours, both of which may be supported by the decreased visibility accompanying poor weather and the dark of the night (Salkind, 2012). Although concurrently complimenting and contradicting the original data, SPSS's Pearson correlation analysis of the NTSB's and NASA's data furnished insightful indications into the relationships between the reported runway incursions and the corresponding meteorological conditions, times of day, and presence of an air traffic control tower.

Conclusions

Seeking to advance aviation operators' awareness of the meteorological and environmental conditions in which the incidence of runway incursions may increase, a case study analysis of the NTSB's and NASA's publically-available incursion data aimed to enhance the growing body of regulatory and instructional knowledge combating incursions across the U.S. Complicating these objectives, although the NTSB's data were comprehensive and credible given their assembly by independent investigators, their limitation to nine reports constricted their generalizability beyond those few reports. Likewise, in spite of the comprehensiveness of NASA's data resulting from their 243 reports, the accuracy and completeness of the data suffered because of their reliance upon user-composed reports of runway incursions, which were not without subjection to error-inducing interference from innumerable sources. Therefore, with the results of a case study analysis constructed upon such data similarly enhanced and hindered, the dual utilization of the NTSB's and NASA's databases aimed to capitalize on their complimentary strengths and surmount their offsetting weaknesses. Finally, given the study's limited sample sizes, the generalizability of the results beyond the study were hindered, but designed as a test case to support future research, the study's focus on the variables' positive and negative relationships offered greater indications of the results of future studies than the numerical representations of the variables' relationships. Providing the preliminary foundation upon which to construct future research exploring the relationships between runway incursions and an increased diversity of meteorological and environmental variables across a greater span of time, this case study analysis concluded that incursions were likelier during VMC, between 0601 hours and 1800 hours, and at airports with an air traffic control tower.

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