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Reducing Runway Incursions at the Nation's Five Busiest Airports, 2009â??2011

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Abstract

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Dissertation Submitted in Partial Fulfillment

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Abstract

During the last decade, the number of runway incursions at airports in the United States and worldwide has increased. The Federal Aviation Administration (FAA) has developed the Runway Safety Program (RSP) to address these concerns and improve the safety of the National Airspace System (NAS). The purpose of this study was to determine whether the FAA 2009–2011 RSP has effectively reduced runway incursions at the nation's 5 busiest airports using data from 3 years before and 3 years after the RSP. A comparison group interrupted time-series design was used to determine the impact of the RSP. A public policy framework served as the theoretical foundation for this study. Data were collected from the FAA on runway incursions occurring from October 1, 2005 through September 30, 2014 and assessed for appropriate inclusion criteria. An analysis of the dataset using chi-square and Mann-Whitney U tests established that though the RSP has made progress, it has not effectively reduced runway incursions at the nation's 5 busiest airports. The RSP has decreased the number of runway incursion caused by air traffic controllers, reduced the overall severity of runway incursions, as well as positively influenced when, during the phase of flight, most runway incursions happen. An increase in pilot deviations suggests finding better ways to reduce these type of runway incursions is critical, especially with the forecasted growth in air travel. Continued deployment of runway safety technology is also important. With increased aviation safety, positive social change will occur through enhanced public safety while traveling, safer working environments at airports, as well as economic stimulus resulting from increased aviation activities benefiting individuals and developing countries throughout the world.

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Dedication

I hereby dedicate this dissertation to my son, Kyle-David Byrne, who missed spending time with his father while this dissertation was completed, but who always encouraged its completion. I further dedicate this dissertation to my youngest brother, Timothy Roy Byrne, who passed away unexpectedly during its completion. May God hold him in the palm of His hand until we meet again. I also wish to thank my parents, Patrick and Diane Byrne, who always instilled in me the value of an education. Finally, I thank the many others who provided me guidance, support and encouragement throughout this arduous adventure.

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Chapter 1: Introduction to the Study

Background

Since the Wright Brothers' first powered aircraft flight on December 17, 1903, aviation and air transportation in the United States and throughout the world has continued to grow significantly (Grant, 2007). In the 21st century, aviation has become a normally accepted part of people's daily lives. Aviation is defined as the branch of science, business, or technology that deals with any part of the operation of machines that fly through the air (Aviation, 2012). With all aspects of aviation, inherent risks are associated with flight operations, especially when multiple aircraft are involved (Federal Aviation Administration [FAA] Flight Standards Service, 2012).

One of the most significant risks in aviation is that one aircraft collides with another aircraft. This danger is increased when multiple aircrafts are conducting operations in close proximity to one another (FAA Flight Standards Service, 2012, pp. 3–6). This risk is further exacerbated when more than one aircraft attempts to concurrently use the same active runway. When an aircraft or other vehicles interfere with the operation of an aircraft on a particular runway, the potential hazard exists for a runway incursion. The FAA (2014d) defined a runway incursion as

> any occurrence at an airport involving an aircraft or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, intending to take off, landing or intending to land within one mile. (p. 1)

A runway incursion is a complex event with unlimited reasons to explain its occurrence, making it difficult to model a standard runway incursion (Feerar, 2003; Rogerson & Lambert, 2012).

Runway incursions at the nation's airports are a growing threat to all of the traveling public and have been the cause of accidents in the past (Schonefeld & Moller, 2012). Air traffic organizations and government administrators have acknowledged a lack of effective preventative measures, and more needs to be done to reduce the potential for runway incursions (Schonefeld & Moller, 2012, p. 32). The largest threat to airplane passengers' safety occurs not while they are flying, but while they are on the runway before or after the actual flight (Ricafort, 2007). Runway incursions have captured the continued attention of the National Transportation Safety Board's (NTSB) list of "Most Wanted" safety improvements for the past decade (FAA Technology Assessment Team, 2002, p. 5). According to Dickey (2005), runway incursions happen frequently and at every airport, creating a risk for pilots, airport employees, and passengers throughout the world (p. 1).

In the last decade, an increase in the number of runway incursions has occurred in the United States (Air Line Pilots Association [ALPA], 2007; Office of the Inspector General [OIG], 2014; Pyke, 2007). Speculation exists regarding the reasons for this increase in runway incursions. Marroquin (2010) argued that the higher rate of runway incursions is a case of mathematics; with more jetliners landing and crossing other runways, the chances of a runway incursion increase. The risk of a runway incursion that could potentially kill hundreds of people is a developing threat, which will increase in likelihood if the forecasted increases in air traffic occur as predicted in the United States during the next 2 decades (ALPA, 2007; FAA, 2013a).

Runway Incursions are a Global Threat

The potential hazards associated with runway incursions are not just a threat in the United States, but also worldwide. During 2013, Italy reported a 40% increase in the number of runway incursions (Mark, 2014). In an effort to combat the threat of runway incursions in their country, Italy's National Flight Safety Agency (Agenzia Nazionale per la Sicurezza del Volo, 2013) issued safety recommendations regarding runway incursions. Canada has also reported an increase in their number of runway incursions, with an incursion happening almost daily (Campion-Smith, 2013). Because of the increasing number of runway incursions, the Canadian Safety Board included runway incursions on its list of the most significant transportation problems posing the largest risk to the traveling public (Campion-Smith, 2013).

The global threat of runway incursions has prompted many countries to seek solutions (Nielsen, 2009). Because of the significant number of runway incursions occurring throughout Europe, including actual collisions resulting in significant loss of life, a European Action Plan for the Prevention of Runway Incursions was implemented (European Organisation for the Safety of Air Navigation [EUROCONTROL], 2011). In this action plan, the inherent dangers associated with runway incursions, their potential causes were identified, as well as which mitigating actions may be effective in reducing them (EUROCONTROL, 2011).

With the increasing frequency of runway incursions worldwide, many countries are developing safety programs designed to reduce the number and inherent threat posed by runway incursions (Nielsen, 2009). The International Civil Aviation Organization (ICAO, 2014) is a specialized agency of the United Nations and develops international Standards and Recommended Practices, which the 191 member countries reference when developing their legally enforceable national civil aviation regulations. The ICAO established that during the past 5 years, one-third of all aviation accidents were linked to runway operations (Werfelman, 2011). Investigators have established a connection between growth in air traffic and an increase in runway incursions, demonstrating that a traffic increase of 20% could result in as much as a 140% jump in the number of runway incursions (Lounsbury, 1999). With air traffic forecast to grow in the United States and throughout the world during the next several decades (FAA, 2013a; FAA, 2015), the threat of runway incursions and the potential loss of life also increases.

The FAA has recognized the danger of runway incursions and has developed a program to address these concerns and improve the safety of the National Airspace System (NAS). The FAA is the federal agency charged with keeping the NAS in the United States operating in a safe and efficient manner (Birtles, Duke, & Sharpe, 2001; Dilger, 2003). The FAA has worked toward the reduction of runway incursions through the creation and implementation of the Runway Safety Program (RSP).

The FAA Runway Safety Program

The RSP was created on November 1, 2002, pursuant to FAA (2002) Order 7050.1. The objective of the RSP is the reduction in the number and severity of runway incursions occurring in the United States (FAA, 2008, p. 5). The RSP works to "promote technology and improve training, procedures, evaluation, analysis, testing, and certification to reduce the risk of runway incursions resulting from errors by pilots, air traffic controllers, pedestrians, vehicle operators, tub operators, and individuals conducting taxi operations" (FAA, 2008, p. 6). The FAA (2002) Order 7050.1 placed the responsibility for the safety program on the newly created Office of Runway Safety, requiring it to work with other FAA organizations as well as the aviation community to identify and implement activities and technologies designed to increase runway safety (p. 2).

The FAA (2002) Order 7050.1 was amended to improve the reporting of runway incursions and also added runway excursions to its coverage. The FAA Order 7050.1A, issued on September 16, 2010, modified FAA Order 7050.1 and adopted the ICAO definition of a runway incursion, allowing for enhanced worldwide uniform reporting of runway incursions. The FAA Order 7050.1B issued on November 11, 2013 modified FAA (2010b) Order 7050.1A by expanding the scope of the RSP to include the prevention of runway excursions. A runway excursion is defined as "a veer-off or overrun off the runway surface" (FAA, 2013b, p. 3).

The FAA (2008) 2009–2011 National Runway Safety Plan established the goals, strategies, and objectives for the RSP for fiscal years 2009 through 2011 (p. 5). This plan's strategy was to reduce the frequency of runway incursions and thereby make runway incursions of any type rare. Ideally, the underlying strategy of reducing the severity of runway incursions would result in only minor rule infractions instead of near aircraft collisions (FAA, 2008, p. 5).

Through the 2009–2011 runway safety strategy, the FAA sought a reduction in the frequency, type, and severity of runway incursions (FAA, 2008, p. 5). According to the FAA (2008), this goal was to be achieved through a vision, a mission, and a set of objectives that provide guideposts and milestones (p. 5). As the ultimate outcome is zero runway incursions, the FAA focused on corrective actions designed to reduce the potential for human error through awareness, outreach, training, technology aids, and infrastructure improvements that enhance situational awareness. The continuing efforts by the FAA include revisions to procedures, changes to airport geometry, and installation of technology and infrastructure designed to mitigate the potential for human error and collisions in the high energy segments of the aircraft's operation (FAA, 2008, p. 5).

One emphasis of the 2009–2011 FAA safety plan was to reduce the opportunity for aircraft collision risk in the high energy segments of the aircraft's operation (FAA, 2008, p. 5). The RSP not only emphasized the importance of the type and severity of a particular runway incursion, but also focused on the "phase of the flight" when the runway incursion happened during the flight operation (FAA, 2008, p. 5). As part of the RSP, each of these three target areas were considered when attempting to reduce runway incursions and are relevant in determining whether the 2009–2011 RSP achieved its goals and reduced runway incursions at the nation's five busiest airports.

The RSP focused on the elements of airport surface safety, including runway incursions and wrong runway departures (FAA, 2008, p. 4). The RSP sought to promote technology; improve training; and enhance the procedures, evaluation, analysis, and testing of runway incursions to reduce the safety risk resulting from errors by pilots, air traffic controllers, pedestrians, and vehicle operators (FAA, 2008). As air travel is expected to increase during the next several decades (FAA, 2013a), a corresponding growth will occur in the number of takeoffs and landings (FAA, 2008). Because of increased flight operations, the potential for runway incursions will also increase (Transport Canada, National Civil Aviation Safety Committee, 2000). Determining whether the FAA 2009–2011 RSP has been effective in reducing the type, severity, and, when during the phase of flight, the runway incursions happened at the nation's five busiest airports was the objective of this study.

Recognizing the need for continued improvement of runway safety, the FAA (2008) has used three primary metrics to assess runway incursions: the frequency, the severity, and type (p. 7). The FAA identifies frequency as the total number of runway incursions within a period of time, severity as how serious a particular runway incursion is in relationship to its causing an accident, and type as the description of the nature of the runway incursion based on the parties involved (FAA, 2008). The FAA through the RSP has invested in programs and technology designed to improve runway safety, asserting that the technologies implemented as part of the 2009–2011 National Runway Safety Plan would prove successful in reducing the frequency and severity of runway incursions (FAA, 2008, p. 15). To assist in the reduction of runway incursions in the United States, other governmental agencies have also investigated the potential causes of runway incursions as well as the FAA's policies and procedures for reducing them.

Other Governmental Agencies' Recommendations to Reduce Runway Incursions

Interested governmental agencies in the United States have also recognized the inherent threat that runway incursions pose to the NAS and have provided the FAA with recommendations to reduce runway incursions (FAA, 2008). The 2009–2011 National Runway Safety Plan addressed the recommendations from the NTSB, the U.S. Government Accountability Office (GAO) and the Office of the Inspector General (OIG) for the Department of Transportation (FAA, 2008, p. 15). These governmental agencies provided recommendations to the FAA (2008) to help reduce the frequency, types, and severity of runway incursions. These recommendations were incorporated into the 2009–2011 RSP (FAA, 2008, p. 15).

National Transportation Safety Board

The NTSB (2015) is an independent federal agency charged by congress to investigate and determine the probable cause of every civil aviation accident in the United States. In their July 6, 2000 safety recommendation letter to the FAA, the NTSB (2000) suggested that runway incursions could be reduced by making modifications to the physical structure at airports as well as procedural changes. These recommendations included installation of ground movement safety systems, amending air traffic control clearance procedures by requiring all runway crossing be made by explicit air traffic control (ATC) instruction (NTSB, 2000, p. 16) and mandating that flight operations complete arrival landing distance assessments prior to every landing using existing performance data and actual conditions, while ensuring a 15% safety margin (p. 16). Though offered by the NTSB in 2000, the FAA did not implement these recommendations into a safety program until their inclusion in the RSP in 2008 (FAA, 2008).

Government Accountability Office

The U.S. GAO (2015) is an independent agency that investigates, conducts evaluations, and performs audits for congress. The GAO performs program reviews and analyses and makes recommendations to improve the efficiency and effectiveness of the federal government (GAO, 2015). In December 2007, the GAO released the Aviation Runway and Ramp Safety Report, which provided recommendations to the FAA designed to assist in their efforts to reduce runway incursions. The GAO (2007) suggested that the FAA use the Office of Runway Safety to lead the agency's safety program, which included preparing a new national runway safety plan, establishing a nonpunitive voluntary safety reporting program for air traffic controllers, and developing an implementation method to collect data on runway overruns that do not result in damage or injury (p. 59). The GAO also suggested that the FAA develop a mitigation plan to address controller overtime issues and work with the aviation industry and the Occupational Safety and Health Administration to develop methods to collect and analyze data regarding ramp accidents as well as develop a strategic plan aimed at reducing accidents in the airport's ramp areas. The FAA incorporated the GAO 2007 recommendations into their RSP (FAA, 2008). Since the creation and implementation of the RSP, the GAO has continued to monitor and provide feedback and recommendations designed to assist the FAA in achieving its objective of reduced runway incursions and increased aviation safety (GAO, 2008a, 2008b, 2009, 2012a, 2012b, 2013, 2014).

Office of the Inspector General

The OIG is a component of the U.S. Department of Transportation. The OIG is an independent auditing group responsible for reporting problems and making recommendations (based on audits, investigations, and inspections) to the Secretary of Transportation and to Congress (OIG, n.d.). In a report on the FAA's progress in reducing runway incursions, the OIG (2010) assessed the actions taken by the agency to identify and correct the causes of runway incursions as well as address the issues that could affect aviation safety throughout the NAS. The OIG recommended that the FAA take actions to help reduce runway incursions. The OIG suggested that the FAA introduce initiatives that increase pilot participation in the Runway Incursion Information Evaluation Program and (a) analyze data collected to identify and mitigate runway incursion causal factors, (b) work with pilots and airline communities to create a process for regional RSP managers to request site-specific redacted Aviation Safety Action Plan information on runway incursions and surface incidents, and (c) develop an automated means to share best practices in reducing runway incursions (OIG, 2010, p. 2). The OIG also suggested that the FAA establish benchmarks for implementing JANUS, National Air Traffic Professionalism Program and Crew Resource Management training, and tower simulator training technologies at airport traffic control towers with a high number of runway incursions caused by controller operational errors. In addition, the OIG suggested that the FAA require the use of safety risk analysis to evaluate existing operational procedures at airports with a potential of runway safety risks and require each line of business to include quantitative goals in its annual business plan for reducing runway incursion risks that are specific to oversight responsibilities.

The FAA implemented the recommendations made by the NTSB, GAO, and OIG as part of their 2009–2011 National Runway Safety Plan (FAA, 2008). The FAA took the following actions: (a) implemented the safety management system (SMS) in the Runway Safety Office, (b) created new and improved training and instruction, (c) created the FAAS Team that would support the General Airport Surface Incident Mitigation Strategy at both the national and regional levels, (d) provided additional outreach throughout the United States, (e) enhanced airport infrastructure designed to recognize potential runway incursions, and (f) developed technology to aid in the reduction of runway incursions and surface incidents (FAA, 2008, pp. 21–25). As a result of these actions, the FAA hoped that the number and severity of runway incursions would diminish. According to the U.S. Commercial Aviation Safety Team, a combination of technologies could increase a flight crew's situational awareness and improve conflict-alerting capability during ground operations, thereby reducing the risk posed by runway incursions by as much as 95% (ALPA, 2007).

A series of new practices and procedures have been implemented in an effort to reduce the number of runway incursions throughout the United States. Although these changes have had a positive effect on reducing the likelihood of a runway incursion, according to government statistics, the number of runway incursions at U.S. airports between 2002 and 2004 remained nearly constant, whereas total air traffic volume decreased by 3% (ALPA, 2007). Despite the implementation of risk mitigation techniques and reduced air traffic volume, the FAA has not reduced the rate of runway incursions. The Air Line Pilots Association (2007) study was one of the factors that prompted the implementation of the RSP (FAA, 2008).

The U.S. Department of Transportation OIG in 2014 issued a report critical of the FAA's progress of runway safety issues. The report asserted that more needed to be done in curtailing runway incursions at the nation's airports and stated "Between fiscal years 2011 to 2013, the number of runway incursions at U.S. airports increased 30 percent, despite slight declines in air traffic operations during that time" (OIG, 2014, p. 14). This ongoing concern about runway incursions previously caught the attention of the U.S. Congress.

U.S. Congress' Concerns Regarding Runway Incursions

The U.S. Congress also recognized the threat that runway incursions pose to aviation safety, especially in light of the anticipated growth in air traffic during the next 2 decades. On February 14, 2012, the President of the United States signed the FAA Modernization and Reform Act (FMRA) of 2012 into law. Section 314 of the Act provided direction to the FAA regarding runway safety (FAA, 2012). The act required that the FAA administrator provide a strategic runway safety plan to congress. The FMRA required that the FAA's strategic runway safety plan include (a) goals to improve runway safety; (b) the near- and long-term actions designed to reduce the severity, number, and rate of runway incursions, losses of standard separation, and operational errors; (c) time frames and resources needed for the actions described in Clause 2; (d) a continual evaluative process to track performance toward the goals referred to in Clause

1; and (e) a review with respect to runway safety of every commercial service airport in the United States and a proposed action to improve airport lighting, provide better signs, as well as improve runway and taxiway markings at those airports (FAA, 2012). The FMRA directed the administrator to address the increased runway safety risk associated with the expected increase in the volume of air traffic (FAA, 2012).

The FMRA (FAA, 2012) directed the FAA's compliance with applicable provisions of the FMRA within a period of 6 months following the act's passage. The administrator must develop a process for tracking and investigating operational errors, losses of standard separation, and runway incursions (FAA, 2012). The resulting data and report to congress had to include procedures for (a) who is responsible for tracking operational errors, losses of standard separation, and runway incursions, including a process for lower level employees to report to higher supervisory levels and for frontline managers to receive the information in a timely manner; (b) conducting periodic random audits of the oversight process; and (c) ensuring proper accountability (FAA, 2012). The administrator's report must also contain a plan for the installation, deployment, and integration of safety systems into the Next Generation Air Transportation System (NextGen) Implementation Plan, which would alert flight crewmembers and air traffic controllers of potential runway incursions (FAA, 2012).

Significant Growth in Air Travel Predicted Through 2034

Aviation forecasts predict a continued and steady growth in air travel with an increased number of passengers flying more miles each year during the next 2 decades (FAA, 2013a). The FAA has previously measured air travel in terms of revenue passenger miles (RPMs). An RPM (n.d.) represents one paying passenger traveling one mile. For U.S. airlines, the agency's FAA (2013a) Aerospace Forecast Fiscal Years 2014 to 2034 projected RPM growth to average 208% per year from 2014 through 2034. Domestic RPMs are forecast to increase at 2.4% annually, and international RPMs are expected to increase by as much as 4.3% annually (FAA, 2013a, p. 80). According to the FAA forecast, the total number of people flying on U.S. airlines will increase by .08% from 2013 levels to 745.5 million in 2014 and grow to 1.15 billion in 2034 (pp. 14–16). With the average percentage of seats filled per flight having reached a record level of 83.2% in 2013 (FAA, 2013a, p. 16), the anticipated growth in air travel has begun.

In addition to the expected increases in passenger travel, air cargo is also expected to increase (FAA, 2013a). Air cargo traffic is measured in terms of revenue ton miles (RTMs), which represents one ton of cargo flown one mile (RTM, n.d.). Air traffic cargo is expected to more than double by 2034 at an average growth rate of 4.1% with load factors expected to reach 83.8% in 2034 (FAA, 2014b, p. 2). Landings and takeoffs at FAA operated control towers are expected to increase from 49.9 million in 2013 to 61.9 million in 2034 (FAA, 2014b, p. 2). As the NAS becomes more complex, the FAA looks toward new technologies to meet the growing demand for safe and efficient air travel in the United States and around the world (FAA, 2014b).

With growth anticipated in air traffic as a result of the increasing number of passenger and cargo flights, the strain on the NAS will likely increase the potential for runway incursions. In addressing these concerns, the FAA has implemented four strategic initiatives. These initiatives include (a) raising the bar on safety by using safety management principles to make smarter, risk-based decisions throughout the agency and with industry and global stakeholders; (b) rebalancing existing services and modernizing the infrastructure, including advancing NextGen, to reduce costs and become more efficient in the long run, as the FAA safely integrates new types of users into the nation's airspace; (c) building on the U.S. history of leadership in shaping international standards to continue to improve aviation safety and efficiency around the world; and (d) attracting and developing the best talent with the appropriate leadership and technical skills to undertake the transformation of the U.S. national aviation system (FAA, 2014b, pp. 1–2).

The expected growth in air traffic both in the United States and worldwide punctuates the need for a method in reducing runway incursions at the nation's airports. The conclusions developed from this research study are significant in determining the effectiveness of the FAA 2009–2011 RSP in reducing the type, severity, and phase of flight implications of runway incursions at the nation's five busiest airports.

The Five Busiest U.S. Airports

The FAA uses criteria when determining which airports in the United States are the busiest. Historically, the two criteria used by the FAA and in most studies to identify the nation's busiest airports were passenger boardings and aircraft movements. When allocating government funds for airports in the United States, the FAA (2014c) uses passenger boardings. A passenger boarding is defined as each time a person gets on and departs in an aircraft (FAA, 1999). The FAA (2014a) has also used the term hub to identify busy commercial service airports. Hubs are categorized by the FAA as large, medium, or small (Heymann, Hans-Joachim, & Norbert, 2006). Large hubs are those airports that account for at least 1% of total U.S. boardings (FAA, 2014a). Medium hubs in the United States are defined as airports that each account for between 0.25% and 1% of the total passenger boardings (FAA, 2014a). Small hubs are defined as airports that account for at least 0.05%, but less than 0.25% of total passenger boardings (FAA, 2014a).

Additionally, the FAA tracks the number of aircraft movements at each towered airport in the United States. An aircraft movement is defined as either a takeoff or landing of an aircraft (FAA, 1999). For this study, FAA data from the last 3 calendar years (2011–2013) of passenger boardings and aircraft movements were used to determine the five busiest U.S. airports. Consistently, both the total passenger boardings and aircraft movements identified the same five busiest U.S. airports. Table 1 displays the FAA's passenger boardings and aircraft movement data for years 2011 through 2013.

Table 1

FAA's Passenger Boardings and Aircraft Movements

	Years					
	2011		2012		2013	
Airports	Passenger boardings	Aircraft movements	Passenger boardings	Aircraft movements	Passenger boardings	Aircraft movements
Hartsfield-Jackson Atlanta International Airport (ATL)	44,414,121	923,996	45,798,809	930,310	45,308,685	911,074
O'Hare International Airport (ORD)	31,892,301	878,798	32,171,743	878,108	32,278,906	883,287
Los Angeles International Airport (LAX)	30,528,737	702,895	31,326,268	698,619	32,427,115	614,917
Dallas/Fort Worth International Airport (DFW)	27,518,358	646,803	28,022,877	650,124	29,018,883	678,059
Denver International Airport (DEN)	25,667,499	628,796	25,799,832	612,567	25,497,348	582,653

The FAA data depicted in Table 1 establishes the five busiest U.S. airports for 2011 through 2013: (a) Hartsfield-Jackson Atlanta International Airport (ATL), (b) O'Hare International Airport (ORD), (c) Los Angeles International Airport (LAX), (d) Dallas-Fort Worth International Airport (DFW), and (e) Denver International Airport

(DEN). With the highest numbers in both passenger boardings and aircraft movements, these airports were used in this study to determine if the FAA 2009–2011 RSP has reduced runway incursions at the nation's five busiest airports.

Problem Statement

Runway incursions continue to create significant safety risks at the nations' airports and will likely increase as air traffic grows during the next several decades (FAA, 2015). As the U.S. agency charged with the responsibility for ensuring aviation safety (Birtles et al., 2001; FAA, 2010), the FAA (2002, 2008) has implemented a program designed to reduce runway incursions. Although the FAA struggles with reducing runway incursions, the best ways to accomplish this objective are still not clear. Determining whether the FAA's methods have been reducing runway incursion is a question that needs to be addressed. Through this study, I sought to answer this question by comparing the types, severity, and phases of flight of runway incursions that have occurred at the nation's five busiest airports before and after the implementation of the FAA's RSP. As such, the problem presented in this research study was whether the FAA's 2009–2011 RSP has reduced runway incursions at the nation's five busiest airports. An increased understanding of the relationship between the types, severity, and phases of flight of runway incursions before and after the implementation of the RSP provides information that will be helpful in improving the way in which the FAA approaches this important safety concern.

Purpose of the Study

Because one of the primary functions of government is to maintain order and safety for its citizens (Lowi, Ginsberg, Shepsle, & Ansolabehere, 2015), ensuring the highest levels of safety within the NAS is of importance. I conducted this study to determine if modifications need to be made to the FAA's RSP. If the same types, severity, and phase of flight runway incursions are occurring both before and after the FAA 2009–2011 RSP report, then changes need to be made to fix the program. The FAA has not addressed the effect of their RSP in terms of whether safety has improved in relationship to types, severity, and phase of flight of the runway incursions at the nation's five busiest airports. This information is essential to determine whether future runway safety programs should be modified.

I conducted a quantitative study between several significant variables identifiable in all runway incursions. According to Creswell (2009), the design of a quantitative purpose statement includes the variables in the study and their relationship, the participants, and the research site (p. 117). Here, the quantitative analysis method allowed me to determine whether the dependent variables (types, severity, and phases of flight) occurring before and after (pre vs. post) the implementation of the FAA 2009–2011 RSP were sufficiently different from one another. The relationship between these variables determined whether the FAA RSP reduced runway incursions at the nation's five busiest airports. The results of this study can be used to improve the effectiveness of future runway safety programs both in the United States and around the world. Public administrators work to create and improve public policies, which help to improve safety and security for its citizens (Lowi et al., 2015).

The FAA is charged with certificating airports pursuant to Part 139 of the Federal Aviation Regulations (FAA, 2016a). To be certificated, the airport must meet established safety requirements (FAA, 2016a, p. 1). When these requirements have been achieved and approved by the FAA, these airports can legally operate commercial aircraft operations. Information resulting from this study will permit the FAA and its public administrators to increase as necessary the applicable standards under Part 139, thereby ensuring enhanced safety within the NAS. With an improved runway safety program, the number, types, and severity of runway incursions should decrease, and the overall safety of the nation's airports should increase, thereby making air transportation safer for the flying public. A worldwide reduction in runway incursions is critical in light of the forcasted growth in flight operations during the next several decades (FAA, 2015).

Nature of the Study

In this study, I focused on improving aviation safety within the United States and throughout the world by reducing the number of runway incursions. By quantitatively analyzing data drawn from the FAA's RSP, I was able to determine whether the FAA RSP is reducing runway incursions at the nation's five busiest airports. Using a summative effect-based evaluation, I analyzed FAA data of runway incursions to determine if any changes in the types, severity, and phase of flight of runway incursions occurred before and after the implementation of the RSP. I used a comparison group, interrupted time series design (Henry, 2010) for this longitudinal study, as data exists to compare the effect of the 2009–2011 RSP before and after the implementation of the RSP. In this manner, the effect of the FAA's RSP, as well as its applicable policies, were determined.

Research Questions and Hypotheses

Literature relevant to program evaluation and runway incursions provided the basis for the questions and hypotheses of this study. According to Creswell (2009), quantitative research questions inquire about the relationship among variables that the researcher seeks to better understand (p. 132). I considered the relationship between variables occurring before and after the implementation of the FAA's 2009–2011 RSP.

Research Questions

Is there a relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP?

Is there a relationship between the severity of runway incursions that occur on the runway before and after the 2009–2011 RSP?

Is there a relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP?

Hypotheses

*H*o1: There is no relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 Runway Safety Program.

*H*a1: There is a relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP.

*H*o2: There is no relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP.

*H*a2: There is a relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP.

*H*o3: There is no relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP.

*H*a3: There is a relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP.

Theoretical Base

According to Kerlinger (1979), a theory is “a set of interrelated constructs (variables), definitions, and propositions that present a systematic view of phenomena by specifying relations among variables, with the purpose of explaining natural phenomena” (p. 64). A public policy framework served as the theoretical foundation for this study. The public policy framework was not only as a guideline for analyzing phenomenon, but also a basis for understanding the significance of unusual findings (Knoepfel, Larrue, Varone, & Hill, 2011).

To determine whether the FAA RSP has reduced runway incursions, I made a comparison between runway incursions occurring before and after the implementation of the RSP. Rosenbaum and Rubin (1983) and Holland (1986) established the theoretical base for using comparative group design when analyzing the effect of policy and programs. Researchers have used impact evaluations using quantitative estimates between comparative groups when establishing the causal effects of programs (Henry, 2010). More specifically, using an interrupted time-series design (a type of comparative group design for measuring the impact of a program) is appropriate for longitudinal studies where data exists for before and after the implementation of the program (Henry, 2010). The interrupted time-series design involves observations of the same variable, which is expected to change because of the effect of the program. The FAA data on the type, severity, and phase of flight for runway incursions occurring before and after the implementation of the RSP were available for analysis. Consistent with the interrupted time-series design, I analyzed these variables to determine the effect of the RSP, and I established the effectiveness of the RSP in achieving its intended purpose of reducing runway incursions at the five busiest U.S. airports.

Definition of Terms

The following provides definitions for the technical terms, jargon, and other special words used in this study.

Aerodrome: A defined area on land or water intended to be used either wholly or in part for the arrival, departure, and movement of aircraft. The term also includes any buildings, installations, and equipment in this area ("Aerodrome," 2012)

Aerospace: The branch of science and technology that deals with travel in the space above the surface of the earth. Aerospace includes travel in the atmosphere and in the vast regions outside of the earth's atmosphere ("Aerospace," 2012).

Air traffic control: The control of aircraft traffic from the ground. Air traffic control is done from control towers with personnel who direct air traffic in the vicinity of an airport and air route traffic control centers whose personnel direct air traffic along the airways between airports ("Air Traffic Control," 2012).

Airport: An area of land or water that is used, or intended to be used, for the landing and takeoff of aircraft and includes its buildings and facilities, if any (Aeronautics and Space, 1962).

Category A (Cat. A): A serious incident in which a collision was narrowly avoided (FAA, 2008, p. 27).

Category B (Cat. B): Separation decreases and a significant potential exists for collision (FAA, 2008, p. 27).

Category C (Cat. C): Separation decreases, but ample time and distance exist to avoid a potential collision (FAA, 2008, p. 27).

Category D (Cat. D): Incident that meets the definition of runway incursion, such as incorrect presence of a single vehicle/person/aircraft on the protected area of a surface designated for the landing and takeoff of aircraft but with no immediate safety consequences (FAA, 2008, p. 27).

Commercial aviation operations: Scheduled or charter-for-hire aircraft used to carry passengers or cargo. Airlines, air cargo, and charter services typically operate these aircraft. The group of aircraft operations includes jet transports and commuter aircraft (FAA, 2008, p. 27).

General aviation (GA): GA operations encompass the full range of activity from student pilots to multihour, multirated pilots flying sophisticated aircraft for business of pleasure. This group of aircraft operations include small GA aircrafts (less than 12,500 lbs. maximum takeoff weight) and large general aviation aircrafts (maximum takeoff weight larger than or equal to 12,500 lbs.). The small GA aircraft tends to be a single-piloted aircraft, such as a Cessna 152 or Piper Cherokee. A corporate or executive aircraft with a two-person flight crew, for example a Cessna Citation C550 or a Gulfstream V, represents the large GA aircraft (FAA, 2008).

Hot spot: A location on an aerodrome movement area with a history or potential risk of collision or runway incursions and in which heightened attention by pilots or drivers is necessary (FAA, 2008; International Civil Aviation Organization [ICAO], 2007).

JANUS: JANUS is a technique designed to improve the data collection process for operational errors by applying human factors principles to develop interventions to enhance performance (FAA, 2008, p. 28). The overall purpose is to understand the role of the individual, situation, and work-related factors as they influence air traffic controllers' operational performance. The objectives are to develop an improved understanding of the human factors relating to individual performance and the occurrence of operational errors and to broaden the role of cognitive factors as they influence the performance of air traffic controllers (FAA, 2008, p. 28).

National Transportation Safety Board (NTSB): An independent U.S. federal agency that investigates every civil aviation accident in the United States and significant accidents in the other modes of transportation conducts special investigations and safety studies and issues safety recommendations to prevent future accidents (FAA, 2008, p. 28).

NextGen Implementation Plan: This plan defines the FAA's path to the Next Generation Air Transportation System. NextGen contains funded commitments to new operational capabilities; new airport infrastructure; and improvements to safety, security, and environmental performance. The plan's management process ensures these will be delivered by a near-term date. The FAA and its partners are also undertaking research, policy and requirements development, and other activities to assess the feasibility and benefits of additional proposed system changes. The goal of this plan is to turn these proposals into commitments and to guide them into use (FAA, 2008, p. 28).

Office of the Inspector General (OIG): The OIG has a responsibility to report, both to the secretary of transportation and to the congress, program and management problems and recommendations to correct them. The OIG carries out these duties through a nationwide network of audits, investigations, inspections, and other mission-related functions performed by OIG components (FAA, 2008, p. 29).

Operational deviation: An occurrence attributable to an element of the air traffic system in which applicable separation minima were maintained, but an aircraft, vehicle, equipment, or personnel encroached on a landing area that was delegated to another position of operation without prior coordinate and approval (FAA, 2008, p. 28).

Operational error: An action by an air traffic controller that results in less than the required minimum separation between two or more aircrafts or between an aircraft and obstacle (e.g., vehicles, equipment, or personnel on runways; FAA, 2008, p. 29).

Pilot deviation: An action of a pilot that violates any federal aviation regulation (FAA, 2008, p. 29).

Runway incursion: 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 takeoff of aircraft (FAA, 2008, p. 29).

Runway incursion error type: Operational error or deviation, pilot deviation, or vehicle or pedestrian deviation. These error types are not necessarily an indication of the cause of the runway incursion; they typically refer to the last event in a chain of pilot, air traffic controller, or vehicle operator actions that led to the runway incursion (FAA, 2008, p. 29).

Surface incident: Any event in which unauthorized or unapproved movements occur in the airport movement area, or an occurrence in the movement area associated with the operation of an aircraft that affects or could affect the safety of flight. A surface incident can occur anywhere on the airport's surface, including the runway. The FAA further classifies surface incidents as either a runway incursion or a nonrunway incursion (FAA, 2008, p. 30).

Vehicle/pedestrian deviation: Vehicles or pedestrians entering or moving on the runway movement area without authorization from air traffic control that interferes with aircraft operations (FAA, 2008, p. 30).

Assumptions

I incorporated several assumptions into this study. The first is that the FAA successfully implemented the RSP as the five busiest U.S. airports. This assumption was based on the fact that the FAA RSP is a national program charged with ensuring the safety of the nation's air traffic control system. I also assumed that the FAA is focused on improving safety at the nation's five busiest airports because they constitute the largest number of passenger boardings and aircraft movements within the United States (FAA, 2008).

Limitations

Limitations were associated with this study and its goal of determining whether the FAA's 2009–2011 RSP has reduced runway incursions at the five busiest U.S. airports. One limitation was that the study was limited to only three dependent variables—types, severity, and phases of flight for runway incursions at these airports. Although I focused on the three critical elements associated with every runway incursion, a broader study considering a larger number of variables could provide even more information regarding runway incursions and the FAA's efforts at reducing them.

An additional limitation of this study was that it was specific to the five busiest U.S. airports. To address the problem of runway incursion throughout the United States, it would be helpful for future researchers to assess all runway incursions at all towered airports in the nation. This study only pertained to the five busiest U.S. airports. At these five airports, professional pilots working for an airline predominantly conduct large commercial aircraft passenger and cargo operations. These complex airport environments necessitate that only highly qualified and experienced air traffic controllers are working at these five locations. These highly qualified and experienced air traffic controllers and predominantly professional pilots are different from the general aviation pilots and air traffic controllers who operate at smaller towered airports geographically located throughout the United States. As such, evaluating runway incursions at the nation's busiest airports was different from at many other smaller airports throughout the nation.

Reducing runway incursions at these other towered airports is also important as a part of reducing runway incursions throughout the United States. Because these smaller airports, which primarily accommodate general aviation aircraft, involve fewer passenger boardings as well as aircraft movements, they are different from the flight operations that occur at the nation's five busiest airports. As such, the results of this study do not present an accurate measure of the effectiveness of the FAA's 2009–2011 RSP across the nation at all towered airports. Future researchers should address these smaller towered airports located throughout the United States.

Delimitations

I addressed whether the FAA's 2009–2011 RSP reduced runway incursions at the nation's five busiest airports; but, several significant delimitations existed. Delimitations are restrictions within a study because of its design (Campbell & Stanley, 1966). I addressed runway incursions at the nation's five busiest airports. Although runway incursions can occur at any airport, this study pertained to the five busiest U.S. airports. These five busiest airports represent a significant portion of the air traffic occurring within the nation (FAA, 2014c). This study was further delimited by the fact that I sought a correlation between only three elements associated with any particular runway incursion. Specifically, I analyzed the types, severity, and phases of flight of runway incursions both before and after the FAA's RSP. Although a number of factors could influence the occurrence of any given runway incursion, I addressed only these three elements. Finally, I explored runway incursions occurring only 3 years before and 3 years after the 2009–2011 RSP. Although runway incursions occurred during the pendency of the 2009-2011 RSP, these runway incursions were not included in this study. Each of these delimitations may have curtailed the results of this study.

Significance of the Study

Runway incursions are a problem with global implications. Although the FAA has worked through the RSP to reduce the number of runway incursions, the effectiveness of the RSP at reducing runway incursions in regard to their type, severity, and phase of flight remain unclear. Through this study, I sought to draw a correlation between runway incursions' type, severity, and phase of flight at the nation's five busiest airports. I chose to study the five busiest airports in this study because they represent approximately 25% of the nation's air traffic (FAA, 2014c), and the FAA has focused a significant portion of its financial and technological resources at reducing runway incursions and increasing safety as these airports (FAA, 2008). By increasing the understanding of the correlation between these variables before and after the implementation of the FAA's 2009–2011 RSP, I developed a more focused picture of the influence of the FAA's RSP. The FAA's limited resources can be more effectively allocated in a manner that will result in an increased effect on the improvement of aviation safety within the United States and throughout the world.

I addressed the question of whether the FAA 2009–2011 RSP reduced the number of runway incursions at the nation's busiest airports. This study fills a gap in the literature associated with runway incursions in that it involved analysis of runway incursions from more than just a numerical perspective; I additionally considered runway incursions regarding the type and severity during the phase of flight when it occurred. Not all runway incursions have the same level of safety implications to the flying public (FAA, 2008). The information garnered from this study provides decision makers with an increased understanding of the effectiveness of the methods employed by the FAA to reduce runway incursions at the nation's five busiest airports. This knowledge will assist the FAA, foreign governments, and other stakeholders in improving their aviation safety programs designed to reduce runway incursions. By improving their runway safety programs, the overall safety of the air travel system throughout the world will improve, thus creating positive social change by improving human and social conditions relating to air travel.

I evaluated the effectiveness of the FAA 2009–2011 RSP at the five busiest U.S. airports. The conclusions drawn from this study will assist in reducing runway incursions and, thereby, help improve the overall safety of the NAS as well as air traffic operations around the world. Making aviation globally safer and reducing the risk for aviation accidents for the flying public supports positive social change.

Implications for Social Change

Positive social change includes improving the quality of life for members of a society through means of social, political, and economic modification. Aviation has presented risks for the flying public throughout the world, including the potential for serious injury and death (FAA Flight Standards Service, 2012). A runway incursion represents a safety risk, which could jeopardize the safety of those using aviation as a means of travel (FAA, 2014d). By reducing runway incursions and decreasing the inherent safety risks associated with aviation, society benefits in several significant ways.

People are more frequently using aviation as a means to travel from one place to another. Aviation within the United States and around the world is expected to continue to grow during the next several decades (FAA, 2015). As the number of flight operations continues to increase, the inherent risk of a potential runway incursion also increases (FAA, 2013a). As larger numbers of people travel, keeping these individuals safe is of primary importance for all government and aviation stakeholders. Additionally, avoiding aviation accidents has the potential of decreasing the overall cost of traveling within the aviation system (Air Transportation Action Group, 2014), which would allow a larger number of people throughout the world to travel by air.

Aviation also helps to stimulate the economies of many countries throughout the world (Air Transportation Action Group, 2014). Tourism, air transport of goods, and many aviation jobs are dependent on the safe operation of the aviation system (Air Transportation Action Group, 2014, p. 2). Reducing the potential for runway incursions and enhancing aviation safety will help improve the inherent safety of air traffic operations throughout the world (FAA, 2014d) and support the growth and further development of aviation. I identified whether the methods used by the FAA are reducing runway incursions. This knowledge can be applied throughout the world when developing and improving aviation safety systems designed to reduce runway incursions globally. The implications resulting from this study have the potential of increasing aviation safety, saving lives, and promoting positive social change. Ultimately, the results of this study will help decision makers worldwide make the right decisions when it comes to how best to reduce runway incursions and improve aviation safety.

Chapter Summary

Solving runway incursions in the United States and around the world is not a simple task. Chapter 1 provided an introduction to the research problem presented in this dissertation. The chapter also provided a summary of the current studies in the area of runway incursions, the underlying theoretical support for the study, and relevant assumptions and limitations. I explored the nature and purpose of this study and described how this study effectively to the body of knowledge in runway incursions and aviation safety, thereby improving the overall safety of NAS and promoting positive social change. Chapter 2 includes a review of the literature pertaining to this study. Chapter 3 provides a discussion of the research design, including a description of the data collection, the research procedure, and the statistical analysis used in the study. Chapter 4 provides the findings and the analysis of the collected data. Finally, Chapter 5 provides a summary, conclusions, and recommendations relative to the study.

Chapter 2: Literature Review

Introduction

I designed this study to evaluate whether the FAA 2009–2011 RSP reduced runway incursions at the nation's five busiest airports. This literature review includes an exploration of literature on runway safety and the effect of runway incursions on aviation safety. The aviation safety literature reviewed relates to runway safety on various concerns and approaches for analyzing and improving runway safety within the United States and throughout worldwide.

Governmental organizations, aviation stakeholders, and academics have developed aviation safety literature in recent years. Aviation safety and more particularly, runway safety, has been a continuing concern of the world's governments, which seek to improve the safety of their own countries' aviation systems and operations. Because governmental entities manage most runway safety programs, I first explored the literature produced by governmental organizations. Next, I explored literature produced primarily within the last 10 years by aviation stakeholders seeking improved aviation safety. I then analyzed academic literature relating to runway safety in this context. GoogleScholar, Academic and Business Premier were databases used to search for literature with key search terms including *aviation*, *airport*, *air traffic*, *safety*, *runway*, *general aviation*, *runway incursion*, *operational error*, *pilot deviation,* and *government program evaluation*. This literature review concludes with an analysis of the literature on government program evaluation, with an emphasis on impact evaluations using comparison group, interrupted time-series design. A basic understanding of government program evaluation methodologies is instrumental in appreciating the quantitative research methodology used in the data analysis of runway incursions at the nation's five busiest airports.

Governmental Aviation Safety Literature

Government literature created by a governmental agency or alternatively a study directed by a governmental agency addresses the significance of runway incursions and their potential disastrous implications on the NAS. In the United States, the FAA predominately created these reports, as well as other interested federal government agencies, such as the NTSB, GAO, OIG, and the Department of Transportation. These governmental agencies have recognized the threat that runway incursions pose to the nation's NAS and have provided the FAA with recommendations to reduce runway incursions. The FAA's 2009–2011 National Runway Safety Plan addressed the recommendations from the NTSB, the U.S. GAO, and the OIG for the Department of Transportation (FAA, 2008, p. 15). Each of these governmental agencies, after conducting independent studies, provided recommendations to the FAA to reduce the frequency, types, and severity of runway incursions (FAA, 2008, p. 15). These recommendations were incorporated into the FAA 2009–2011 RSP (FAA, 2008, p. 15).

National Transportation Safety Board

The NTSB (2015) is an independent federal agency charged by congress to investigate and determine the probable cause of every civil aviation accident in the United States. In their July 6, 2000, safety recommendation letter to the FAA (NTSB, 2000), the NTSB suggested that runway incursions could be reduced if the FAA took the following actions,

> Require all airports to provide scheduled passenger service and install a ground movement safety system that would provide direct warnings to flight crews regarding potential runway incursions (NTSB, 2000, p. 16).
>
> Amend Title 14 Code of Federal Regulations §91.129(i) (Aeronautics and Space, 1962) to require that all aircraft runway crossings be authorized only by ATC instructions or clearances, and further ensure that all personnel assigned to move aircrafts and pilots operating aircrafts receive adequate notification of the change in ATC procedures (NTSB, 2000, p. 16).
>
> Amend FAA Order 7110.65 involving air traffic control procedures that require aircrafts crossing multiple runways be issued ATC crossing instructions for each runway after the aircrafts have crossed the previous runway (NTSB, 2000, p. 16).
>
> Mandate that all 14 Code of Federal Regulations Parts 121, 135 and 91 (Aeronautics and Space, 1962), as well as Subpart K aircraft operators conduct arrival landing distance assessments before every landing based on existing performance data, actual conditions, and incorporating a minimum safety margin of at least 15% (NTSB, 2000, p. 16).

Each of these actions was designed to reduce runway incursions by modifying or implementing new procedures, which the NTSB believed would be beneficial in increasing aviation safety within the NAS through the reduction of runway incursions. Though the NTSB suggested these recommendations in 2000, the FAA first implemented these in their 2008 RSP (FAA, 2008, p. 15).

Government Accountability Office

The U.S. GAO (2015) is an independent federal agency that investigates, conducts evaluations, and performs audits for congress. The GAO investigates how government agencies spend taxpayer monies to achieve their mandated duties. The GAO has performed numerous evaluations of the FAA's aviation safety programs and its continuing efforts to improve the safety of the NAS. These evaluations have helped in shaping the course that the FAA has taken in its endeavors to reduce runway incursions at the nation's airports.

In December 2007, the GAO released its report providing guidance to the FAA regarding the agency's efforts to reduce runway incursions. The GAO (2007) developed its findings through a review of runway and ramp safety data, interviews conducted with industry experts and FAA officials, as well as surveys of aviation experts (pp. 61–79). The GAO findings were critical of the FAA's methods for reducing runway incursions (GAO, 2007). The GAO report made five recommendations to positively influence the FAA's efforts to reduce runway incursions throughout the United States (GAO, 2007).

1. Create of an Office of Runway Safety that would develop and implement a new national runway safety plan;
2. Create a nonpunitive voluntary safety reporting system to encourage air traffic controllers to disclose operational errors and deviations;

3. Collect data on runway overruns by aircraft that do not result in damage or injury to analyze trends and causes of these types of incidents;
4. Develop a plan for handling air traffic controllers overtime issues, which focus on shift changes and incentives, to encourage transfers to locations with higher volumes of traffic thereby necessitating significant rates of controller overtime; and
5. Enhance collaboration with the aviation industry and the Occupational Safety and Health Administration to develop methods to collect and analyze ramp accidents and, if necessary, create a strategic plan designed to reduce accidents involving passengers, workers, as well as the aircraft in airport ramp areas. (GAO, 2007, p. 59)

Each of these recommendations was implemented by the FAA when developing its RSP (FAA, 2008).

The GAO continued its audits of the FAA's efforts to improve aviation safety and reduce runway incursions (GAO, 2008a, 2008b, 2009, 2012a, 2012b, 2013, 2014). The GAO (2008a) found that the FAA's progress on reducing runway incursions had been impeded by a lack of leadership, challenges involving technology implementation, and other problems. The GAO findings were based on surveys of experts regarding the causes and measures to mitigate accidents, review of relevant safety data, and interviews of industry and FAA officials (GAO, 2008a, p. 1). With knowledge of the increasing NAS congestion and recent data indicating that runway incursions serve as precursors of aviation accidents, the GAO (2008a) found that more needed to be accomplished by the

FAA to reduce runway incursions (p. 1). Although the FAA has taken steps to reduce runway incursions, a lack of leadership and coordination, technology challenges, data limitations, as well as human factors have impeded the agency's progress (GAO, 2008, p. 1). The GAO (2008a) found the development of leadership, overcoming technology challenges and data limitations, as well as resolving human factors as measures necessary for the FAA to overcome to achieve its runway safety goals (p. 13).

The GAO (2008b) found that even though the FAA had worked toward achieving its goal of reducing runway incursions within the United States, the agency's continued efforts through changing airport layouts, improving runway signage, modifying airport lighting and markings, as well as developing and implementing new technology designed to increase situational awareness were essential for continued safety improvement (pp. 1–2). The GAO (2008b) found that even though the FAA had implemented several methods for scheduling air traffic controller shift changes to overcome human factor implications, air traffic controllers were hesitant to self-report operational errors and deviations when the possibility of discipline existed (p. 16). Additionally, air carriers have taken steps to reduce the potential for runway incursions by educating their pilots on cockpit distractions and how to avoid them (GAO, 2008b). The NTSB and the FAA have also acknowledged that runway status lights (RWSL) would be helpful in reducing runway incursions at the nation's airports. The GAO noted that although the FAA had been making progress to improve aviation safety, more still remained to be accomplished.

The GAO (2009) emphasized the importance of adequate and predicable funding for the FAA to accomplish its safety goals. Using generally accepted government auditing standards through discussions with senior FAA officials and aviation industry representatives, the GAO specified six primary areas of importance for increased aviation safety and the continued development of a safer NAS. These areas of primary importance included (a) NextGen: implementing existing and current technologies while providing incentives for the acquisition of these technologies for airlines as well as enhancing runways, thereby exploiting the advantages of NextGen technologies (GAO, 2009, pp. 1–2); (b) safety: the FAA should increase aviation oversight, especially of runway and ramp areas, through the use of improved aviation safety data (pp. 3–4); (c) mobility: the FAA should decrease congestion through an increase of NAS capacity by reducing delays with redesigned airspace and limiting flight operations (pp. 5–6); (d) environment: the FAA should work on reducing emissions, noise, and other pollutants (pp. 7–8); (e) human capital: the FAA should develop a fully trained workforce capable of implementing the demands required by NextGen (pp. 9–10); and (f) timely reauthorization: timely reauthorizations of FAA funding is essential to support continuing programs and ensure the successful implementation of the NextGen provisions (pp. 11–12). Congress' FAA funding reauthorization occurred in 2012 (FAA, 2012).

The GAO (2012a) credited the FAA with taking the steps to improved aviation safety data, but indicated that aviation safety risks still required immediate attention. The GAO reached the conclusions in their report by reviewing earlier GAO work as well as the actions of the FAA in response to the earlier GAO (2007, 2008a, 2008b, 2009) aviation safety reports. In their report, the GAO (2012a) noted that in 2010, Congress passed the Airline Safety and Federal Aviation Extension Act, which addressed concerns for reducing safety risks through more effective FAA management. In responding to congress' concerns, the FAA has worked to implement new safety programs and used the SMS, a risk-based aviation safety approach that incorporates data that helps in the creation of effective policies, procedures, and accountabilities (GAO, 2012a, p. 13). The GAO (2012a) suggested that the FAA focus increased attention on improving the quality of its data, while recognizing that more work in aviation safety remained to be accomplished by the FAA (p. 14).

In late 2012, congress requested that the GAO (2012b) perform an analysis of the trends in general aviation accidents that have occurred between 1999 and 2011. These trends, which included runway incursions, affect the overall safety of the NAS (GAO, 2012b, pp. 1–2). The GAO (2012b) developed its findings using generally accepted government auditing standards through an analysis of NTSB accident data, interviews of NTSB officials, members of the FAA and industry stakeholders, as well as a review of government and industry studies (p. 37). In addition to the implementation of new technologies, the GAO concluded that to improve general aviation safety, the FAA required higher quality data of general aviation flight hours. The FAA was further encouraged to establish general aviation performance measures necessary for the development of a 5-year general aviation safety strategy (GAO, 2012b). As the importance of general aviation on the NAS continues to increase, an increased FAA understanding and effective regulation of general aviation is necessary for reducing runway incursions and improving aviation safety throughout the NAS.

The GAO (2013) concluded that the FAA does not have a comprehensive risk-based process for the effective reporting of aviation safety issues. The GAO recommended that the FAA implement improved data collection methods and analysis focused on runway and ramp safety, airborne operational errors, and the development of more information regarding general aviation flight hours and training (GAO, 2013, pp. 4–5). Although the GAO (2013) recognized that the FAA has moved toward higher levels of safety, the agency still faces challenges in other aviation safety areas (pp. 5–10).

The GAO (2014) reviewed SMS implementation progress at the FAA and within the aviation industry. The GAO explored the challenges affecting the implementation of SMS and received recommendations from stakeholders regarding how the deployment of SMS could be enhanced (GAO, 2014, pp. 1-3). The GAO (2014) used generally accepted government auditing standards when conducting research through the review of FAA documents and interviewing FAA officials and 20 selected aviation stakeholders, including air carriers, repair stations, manufacturing firms, and certificated airports (pp. 31–34). The GAO established that confusion still existed by stakeholders regarding the SMS oversight strategy. Many aviation safety inspectors needed additional training in SMS procedures as well as an improved understanding of the agency's procedures so that consistent interpretation would occur with regulatory enforcement (GAO, 2014). The GAO found that stakeholders believed that the FAA's collaboration and training were good, but could be improved and that SMS training provided by the FAA for stakeholders would be helpful. The GAO (2014) recommended that the FAA establish a plan for SMS implementation with a plan for the training and guidance of the agency's aviation safety inspectors while they perform their regulatory duties. Accomplishing the efficient implementation of SMS would serve as a tool for further reduction of runway incursions and an increase in aviation safety throughout the NAS.

Office of the Inspector General

The OIG is a component of the U.S. Department of Transportation and an independent auditing group responsible for reporting problems and making recommendations (based on audits, investigations, and inspections) to the secretary of transportation and to congress (OIG, n.d.). In a report on the FAA's progress toward the reduction of runway incursions, the OIG (2010) assessed the actions taken by the agency to identify and correct the underlying causes of recent runway incursions as well as address those issues that could affect aviation safety throughout NAS. The OIG recommended that the FAA take six actions to help in the nationwide reduction of runway incursions:

> Establish initiatives to promote increased voluntary pilot participation in the Runway Incursion Information Evaluation Program and ensure the analysis of data collected to identify and mitigate runway incursion causal factors;
>
> Collaborate with the pilot and airline communities to establish a process whereby regional RSP managers can request site-specific redacted Aviation Safety Action Plan information on runway incursions and surface incidents to aid in identifying trends, root causes, and possible local solutions;

Develop an automated means to share local best practices that were successful in reducing runway incursions;

Establish appropriate milestones for implementing JANUS, National Air Traffic Professionalism Program and Crew Resource Management training, and tower simulator training technologies at airport traffic control towers that have a history of a high number of runway incursions caused by controller operational errors;

Require a safety risk analysis to evaluate existing operational procedures at airports where the FAA has identified potential runway safety risks and train appropriate personnel in conducting such analysis; and

Require each line of business within the FAA to include quantitative goals in its annual business plan for reducing runway incursion risks specific to oversight responsibilities. Designate the Runway Safety Office as the authority to review and approve all runway safety initiatives. (OIG, 2010, p. 2).

The OIG's (2010) recommendations promote increased collaboration between aviation industry stakeholders and encourage improved safety risk analysis, better training, and the sharing of best practices designed to increase aviation safety and reduce runway incursions at the nation's airports.

International Governmental Runway Incursion Literature

In addition to the literature provided by federal government agencies, international governmental organizations have also been helpful through their efforts to reduce runway incursions. These international organizations represent the many countries that have struggled to reduce runway incursions occurring within their nations. Their efforts have led to the development of literature regarding the global threat and worldwide challenge seeking the reduction of runway incursions and increasing aviation safety. The Australian Transport Safety Bureau (2004) concluded that a majority of runway incursions were because of communication problems between the air traffic controller and another party, most often the pilot. The ICAO (2002), a component of the United Nations, emphasized human factors and organizational issues of airline maintenance operations and how such improved procedures could be beneficial in reducing runway incursions throughout the world. The ICAO's engagement in this endeavor has also served as a catalyst for other organizations' safety efforts.

The International Air Transport Association (2006) examined the human, technical, environmental, and organizational components associated with its accident classification system and underlying aviation risk assessment. Although researchers have evaluated the ways to reduce the number of runway incursions, several have specifically focused on reducing runway incursions by applying technological advancements (Horowitz & Santos, 2009; Schonefeld & Moller, 2012).

Nongovernmental Aviation Safety Literature

In several nongovernmental aviation safety studies, researchers have concluded that major U.S. airports are operating with unacceptable levels of risk because of their inherent potential for runway incursions and their failure to adequately address these safety concerns (ALPA, 2007; NTSB, 2010). Skorupski (2010) established that air transport is a complex system that must effectively combine advanced technical systems, operators (air traffic controllers and pilots), and procedures (p. 45). Historically, aviation safety risk has been identified by the number of aircraft accidents, which typically results in a large number of casualties and huge financial loses for those involved (Skorupski, 2010, p. 45). Because of the significant exposure which could result from an aviation accident, safety has remained an essential component in air transportation (Skorupski, 2010).

According to Skorupski (2010), the risks inherent in air traffic can be separated into conscious and unconscious. Conscious risk occurs when, despite the possibility of avoiding it, someone decides to engage in a risky action (Skorupski, 2010). Meanwhile, unconscious or passive risk occurs independently of anyone's will or decision (Skorupski, 2010). Dependent on the nature and duration of the inherent safety threat, an operator may have to deal with continuous, single, or cumulative risks. Air traffic accidents are generally characterized with respect to risk and have several distinctive features: (a) aircraft crew members and passengers are the most vulnerable to risk; (b) accidents are rare events but have serious consequences; and (c) risk is always present in aircraft operations and requires that noncumulative risk be properly addressed (Skorupski, 2010, pp. 46–47).

Managing risk and safety effectively is a practical problem, which has historically been addressed by examining the underlying causes of incidents and accidents, identifying the risks associated with them, and then determining appropriate safety standards consistent with socially acceptable values (Skorupski, 2010, p. 47). According to Skorupski (2010), a number of methods and models exist to consider the different aspects of risk inherent in air transportation. The most advanced methods and models frequently used involved studying the causes of actual incidents and accidents. A second group of methods and models focused on the theoretical risk of possible collisions in air transportation. A third group of methods and models focused on human error analysis, which occurs because of errors by air traffic controllers and pilots. The fourth and final group of risk analysis methods focused on third-party risk methods, which involve considering the statistical risk of losing human life while on the ground through an aircraft accident as compared to the inherent risk associated with the aircraft passenger (Skorupski, 2010, p. 47).

Skorupski (2010) established that air traffic accidents are most often a combination of many different factors. Skorupski (2010) focused his analysis on evaluating only those additional factors that determine the creation of the accident for the purpose of determining the statistical dependencies between a serious incident and the air accident (p. 47). Skorupski concluded that it would be possible to estimate the number of accidents solely based on the knowledge of the number of incidents on the presumption that a serious incident results in an accident through only one additional adverse event (p. 53). As such, Skorupski asserted that a realistic forecasting model can be developed to identify that number of accidents based on the number of incidents (serious incidents) occurring in air traffic (p. 53).

The National Aeronautics and Space Administration (NASA; 2005), FAA (2009), and European Organisation for the Safety of Air Navigation (EUROCONTROL; 2010) concluded that the Runway Incursion Prevention and Alerting System (RIPAS) has the potential to significantly decrease the number of runway incursions, thereby decreasing the overall risk of an aviation accident (Jones & Prinzel, 2011). Some researchers have concluded that even with RIPAS installations, general aviation will still pose an unacceptable risk, affecting runway safety at many airports (Schonefeld & Moller, 2012). Although an open question appears to exist regarding the eventual effect of RIPAS (Chapin, 2010), the experience from the deployment of RWSL and the final approach runway occupancy signal (FAROS) have established that direct visual clues at airports significantly improve an airport's overall runway safety (FAA, 2009).

Aviation safety literature supports the conclusion that new technologies could have a beneficial effect on the reduction of runway incursions (Schonefeld & Moller, 2012). However, many of these technologies are expensive and require a significant capital investment. Horowitz and Santos (2009) explored how policy makers could approach technological improvements designed to cost-effectively improve runway safety at their respective airports (p. 357). The objective of the Horowitz and Santos' (2009) study was to identify the best ways to install technological improvements while decreasing the rate of runway incursions and ensuring that current airport safety levels are not adversely affected (p. 357). Utilizing a case study approach, Horowitz and Santos (2009) concluded that the best way in which to introduce technological improvements into an operational airport environment was by using the new technology initially as a secondary airport safety system, which could then assist in the reduction of runway incursions while still maintaining acceptable levels of airport safety (Horowitz & Santos, 2009, p. 357). In this manner, effective data collection regarding the technological improvement could occur without increased risk to overall aviation safety (Horowitz & Santos, 2009, p. 360).

The causal relationship between human factors and the occurrence of runway incursions at the nation's airports has been the central focus of several aviation safety studies (Chang & Wong, 2012; International Air Transport Association, 2006; Rantanen, Palmer, Wiegmann, & Musiorski, 2006). These studies have consistently concluded that human error serves as a significant factor in most runway incursions.

Rantanen, Palmer, Wiegmann, and Musiorski (2006) identified human error as a consistent and primary factor resulting in aviation accidents (p. 1221). The International Air Transport Association (2006) concluded that a pilot's years of flying, flying hours and flying skills has an influence on their likelihood of having a runway incursion. Chang and Wong (2012) analyzed runway incursions from the human perspective, concluding that most runway incursions are the result of human error and that statistically pilot deviations are the most significant causal factor in a majority of runway incursions (p. 25), with pilot error the primary cause of most runway incursions (p. 30). The FAA data supported Chang and Wong's conclusions that nearly 72% of runway incursions involve pilot deviations while operating as general aviation aircraft (Chang & Wong, 2012, p. 25). As a result of their findings, Chang and Wong (2012) created a model for analyzing human risk factors designing it as an effective tool to reduce runway incursions (p. 25).

Chang and Wong's (2012) model established an overall ranking and relative weighting of dimensions of the top 10 pilot risk factors resulting in runway incursions.

These factors included (a) situational awareness, (b) runway/taxiway marking and signs, (c) safety attitude, (d) communication between pilot and air traffic controller, (e) communication skills, (f) fatigue/incapacitation, (g) pilot's cross-check, (h) instruction and read back between pilot and ATC, (i) airport illumination, and (j) runway incursion prevention systems (Chang & Wong, 2012, p. 28). Each of these risk factors frequently play a critical role in an eventual runway incursion.

Using Chang and Wong's (2012) model to identify areas of potential runway incursions on an airport by effectively identifying those pilot risk factors that could potentially reduce runway incursions, thereby decreasing the number of potential runway incursion accidents and reducing the risk of fatalities and financial lost by the airlines (p. 30). Chang and Wong also determined that there were significant differences between the pilots' viewpoints of those risk factors likely to result in runway incursions as compared to the viewpoints of airline management experts. Pilots considered operational deviations/negligence, a lack of teamwork and pilot fatigue as critical factors, while airline management experts considered decision making ability, flight dynamics surface guidance systems and runway incursion prevention systems as the primary factors leading to runway incursions (Chang & Wong, 2012, p. 29). Pilots generally focused on their core ability to interact with others, whereas airline management experts emphasize the failure of ineffective interaction between pilots and hardware (Chang & Wong, 2012, p. 29). From the experts' viewpoint, most runway incursions could be most effectively avoided with enhanced hardware assistance and improved liveware (Chang & Wong, 2012, p. 29).

A system organization perspective has been utilized to understand the factors influencing aviation safety as well as the causes and potential solutions of runway incursions at the nation's airports (Adam, Lentz, & Blair, 2002; Rogerson & Lambert, 2012). Adam, Lentz, and Blair (2002) studied factors claimed as positively influencing the likelihood of a runway incursion occurring under a given set of circumstances. These factors varied significantly in type and included such components as runway layout, airport identifications, signage as well as the methods utilized for navigation and communications among pilots, drivers, and controllers (Adam et al., 2002). Rogerson and Lambert (2012) established a method for distinguishing levels of risk across a set of locations on an airport utilizing multiple factor hierarchies (p. 22). This method avoids averaging across experts and is thus useful for situations in which experts disagree and in which an absence of expert consensus on the causative or contributing factors are significant for risk management purposes (Rogerson & Lambert, 2012, p. 23). Rogerson and Lambert's research findings established that using experts' perspectives on the airport-specific factors could actually contribute to runway incursions. Their study involved the analysis of 80 towered airports in the United States where experts identified and weighed the relative influence of factors such as: airport geometry, operations, weather, geography and the number of days since the last safety review in determining the likelihood of a future runway incursion (Rogerson & Lambert, 2012, p. 22). By analyzing these factors, a prediction of the relative likelihood of a runway incursion occurring at a particular location could be effectively calculated (Rogerson & Lambert, 2012, p. 23).

Through their detailed factor analysis, Rogerson and Lambert (2012) expanded the scope of their research and developed a methodology for identifying, organizing, and aggregating potential risks to a safety-critical system that could then be used to create a protocol for the prioritization of protections against airport safety hazards (pp. 22–23). Rogerson and Lambert's (2012) methodology was designed to avoid the acceptance of unfounded expert views by highlighting the effects of multiple complementary perspectives on system organization while addressing the process of decision-making under stakeholder-specific assessments of risk factor relationships (p. 23). Ultimately, this modeling process could be effectively applied to a particular case study where more productive training meetings would occur which were specifically designed to improve the local airport runway safety environment (Rogerson & Lambert, 2012). As such, Rogerson and Lambert asserted that particular airport runway safety problems could be effectively resolved by identifying the indicator and causative factors and then prioritizing which airports warrant special training or intervention by the program safety office. In this manner, limited government resources could be more efficiently allocated to those airports and locations where the resulting outcome would be more significant (Rogerson & Lambert, 2012, p. 25). Those areas identified on an airport where a runway incursion would be more likely to occur were called "hot spots" (Rogerson & Lambert, 2012, p. 25).

The concept of airport hot spots was a reflection on a similar concept within the federal highway system, commonly referred to as "conflict points" (Federal Highway Administration, 2010). Conflict points are locations where traffic accidents are more likely to occur, likewise hot spots are locations on airports where runway incursions or accidents are more likely to happen (Rogerson & Lambert, 2012, p. 25). Because each hot spot presents a potential location for a runway incursion, the higher the number of hot spots at a particular airport, the higher the likelihood of a runway incursion (Rogerson & Lambert, 2012, p. 25). Rogerson and Lambert (2012) further identified those factors that would have an effect on the likelihood of a runway incursion (p. 26). These factors included such aspects as airport culture, management style and method of communication (Rogerson & Lambert, 2012, p. 26). Rogerson and Lambert (2012) organized 23 runway incursion factors into a seven factor hierarchy to account for varying perspectives among stakeholders on the particular emphasis factor and its relationship among the factors that might be present at any given airport location (p. 33).

Kim and Yang (2012) took a different approach in identifying risk frequency of hazards related to runway incursions. They developed an analytical hierarchal process wherein 15 hazards were weighted in such a manner that the area with the highest score was more likely to become an area where runway incursions would happen in the future (Kim & Yang, 2012, p. 30). Kim and Yang (2012) established that hazards causing runway incursions varied depending upon the airport's environment and operational characteristics (p. 31). The researchers further concluded that the largest contribution to runway incursion was a "misunderstanding of ATC's instructions," followed by a "momentary forgetting/confusion" of a clearance issued, misidentification of an aircraft/vehicle or its location, and loss of situational awareness (Kim & Yang, 2012, p. 34). As such, training in these critical areas was essential in order to reduce the number of runway incursions. If runway incursion locations could be effectively identified, then methods and technologies designed to reduce the chance of these runway incursions happening at these locations in the future was critical.

Schonefeld and Moller (2012) provided a methodology for developing and implementing technological responses designed to prevent runway incursions (p. 31). From a theoretical perspective, runway incursion prevention technology has been primarily premised on protective measures designed to inhibit those causes that oftentimes lead to runway incursions and additionally provide timely alerts which make pilots and others aware of a potential runway incursion. According to Schonefeld and Moller (2012), previous and current studies have uniformly agreed that positive situational awareness was a primary preventative key in avoiding runway incursions and safely mitigating them should they occur (p. 35). If proper technological advancements were made available and implemented by the airports, Jones and Young (2001) had previously estimated an 80% reduction in runway incursions would result by effectively enhancing the situational awareness of flight crews and air traffic controllers.

Schonefeld and Moller (2012) concluded that there were two basic approaches to preventing runway incursions - avoid entering an active runway and timely detecting an imminent runway incursion so that the situation could be effectively resolved (p. 35). The ability to timely prevent a runway incursion has been frequently dependent on the type of surveillance system that provides the information to the individual handling the runway incursion problem (Schonefeld & Moller, 2012, p. 35). Previous research has also supported that reliable, effective and accurate surveillance systems at airports, which effectively monitor aircraft movement areas, has had a positive influence on the reduction of runway incursions (Jones, Quach, & Young, 2001; Jones & Young, 2001; Singh & Meier, 2004: Squire, Barrow, Durkee, Smith, & Moore, 2010).

Determining which surveillance system best suites a particular airport environment has been a relatively recent research topic. One type of surveillance system designed to reduce runway incursions has been the Runway Incursion Prevention and Alerting System (RIPAS). Stevens and Sanchez (2010) found that the integration of RIPAS into the workflow of an air traffic controller (ATC) oftentimes depends on the reliability of the surveillance technology. RIPAS is capable of immediately reacting to aircraft route deviations that could result in a runway incursion and then providing direct and timely situational information to both the flight crew and the air traffic controller in order to prevent a runway incursion (Squire et al., 2010).

Theoretically, if RIPAS achieved its stated objective, then there should not only be a decrease in the number of runway incursions as well as the events leading to potential runway incursion, but also a corresponding decrease in the severity of the runway incursion should also occur (Schonefeld & Moller, 2012, p. 36). This theory was premised on the fact that aircraft traffic depends on a series of decisions by humans, which without adequate information can result in poor outcomes (Schonefeld & Moller, 2012, p. 36). With the quality of information enhanced through effective technology, poor decisions can be effectively minimized (Schonefeld & Moller, 2012, p. 36). Schonefeld and Moller (2012) further asserted that any remaining poor decisions would be identified by surveillance technology and a sound warming alert would occur, thereby further reducing the likelihood of a runway incursion (p. 36).

Studies from NASA (2005), FAA (2009), and EUROCONTROL (2010) also concluded that technologies such as RIPAS and Runway Incursion Advisory and Alert System (RIAAS) have the potential to significantly decrease the number of runway incursions, thereby reducing the overall risk of an aviation accident (Jones & Prinzel, 2011). NASA (2005) research, conducted jointly by NASA Langley Research Center and Rannoch Corporation, explored the potential safety advantages associated with the implementation of RIASS. Similar to RIPAS, RIAAS provides alerts to pilots through an aircraft-based alerting system (NASA, 2005, p. 1). The research was premised upon three component parts, including an Airborne Research Integrated Experimental System (ARIES), aircraft mission simulator and eight commercial airline crews (NASA, 2005, pp. 7-8). These tests were conducted under various meteorological conditions utilizing several cockpit technologies (NASA, 2005, p. 8) and also incorporated a pilot survey regarding their opinions about the Runway Incursion Prevention System (RIPS).

The survey revealed that pilots unanimously felt that RIPS technology created a safer cockpit environment, while 75 percent believed the alerts they received through RIPS were timely and allowed them an adequate opportunity to effectively react to pending aviation conflicts (NASA, 2005, p. 8). Meanwhile, the studies' flight tests established the reliability of the systems cross-runway alerting logic with only a small number of missed alerts generally resulting from traffic ADS-B data interface problems (NASA, 2005, p. 9). The research also utilized a simulator, which developed data through a series of standard runway incursion scenarios with real-time traffic (NASA, 2005, p. 9). An analysis of the data established that RIAAS alerts provided adequate time for safe evasive maneuvers (NASA, 2005, p. 10). NASA (2005) concluded that the integration of RIAAS could reduce the risks associated with severe runway incursions (p. 13). It further determined that RIAAS would have significant influence at airports without automated aircraft ground movement surveillance systems (NASA, 2005, p. 13). Even at airports with ground surveillance systems, substantial benefits resulted from RIAAS alerts to pilots with a minimum number of false alerts when a conflict was not actually present (NASA, 2005, p. 13). In conclusion, NASA (2005) research established that the RIAAS aircraft alerting system was valid and effectively reduced runway incursions at airports, thereby increasing runway safety (p. 13).

The FAA (2009) research focused on educating aviation stakeholders on multifaceted approaches for the reduction of runway incursions at the nation's airports. As part of the study, more than 40 aviation leaders from various airports, airlines, pilot unions, air traffic controllers, and aerospace manufacturers worked collectively to identify those sections of the NAS which could be vulnerable to human error, thereby increasing the chance of a runway incursion (FAA, 2009, p. 2). The stakeholders worked collectively to improve cockpit and air traffic procedures, safety markings, airport signage as well as technology and training (FAA, 2009, p. 8).

These stakeholders further addressed proposed FAA strategies for increased improvement in runway safety (FAA, 2009, p. 8). Additionally, they recommended that enhanced communications procedures be established between fellow cockpit crewmembers as well as more effective coordination with and between air traffic controllers (FAA, 2009, p. 8). These stakeholders concluded that with more explicit taxi instructions between controllers and flight crews, the levels of situational awareness and control of aircraft movements on the airport will increase (FAA, 2009, p. 8). Recommendations were also encourage for updates in applicable standards for airport signage and markings (FAA, 2009, p. 8) as well as improved technological implementation such as RIAAS or RIPAS within the cockpit and control towers (p. 9).

FAA (2009) emphasized the importance of timely implementation of runway safety-enhancing technologies at airports throughout the United States (p. 9). These technologies included Airport Surface Detection Equipment, Model X (ASDE-X), FAROS, and RWSL (FAA, 2009, p. 9).

Runway Status Lights alerts pilots to potential runway incursions using a system of lights embedded into runway surfaces, which results in pilots obtaining enhanced situational awareness and providing increased assistance in avoiding potential aircraft accidents (FAA, 2009, pp. 22–23). The ASDE-X serves as a method of surface detection equipment technology that enables air traffic controllers to detect potential runway incursion conflicts before they occur (FAA, 2009). Additionally, the electronic flight bag and airport moving map display provide pilots with information regarding a variety of aviation topics and can improve situational awareness through increased surface safety. Finally, FAROS uses flashing lights visible to pilots on approaching aircrafts to warn them that the runway is occupied, thus preventing accidents and incursions on airport runways (FAA, 2009). By the end of 2011, each of the airports analyzed in this dissertation had installed these technologies (GAO, 2013).

The impetus for EUROCONTROL (2010) was the significant number of runway incursions that could potentially result in an aircraft accident. The study expressed concerns that with increasing levels of air traffic throughout the world as well as an increased pressure on efficient operations during all phases of flight, a growing threat of aircraft incursions and accidents exists (EUROCONTROL, 2010, p. 9). With increased concern regarding the whole airport environment, expanding the focus of airport surface safety nets to include taxiways and airport apron areas and the introduction of integrated surface safety net functions was important. Surface safety nets, which incorporate technologies, such as RIAAS and RIPAS, alert air traffic controllers, flight crews, or vehicle drivers to potentially hazardous situations in an effective manner with sufficient warning time for the situation to be resolved (EUROCONTROL, 2010). Surface safety nets rely on Airport Safety Roadmaps that build on operational requirements laid out by ICAO and are supported by an operational analysis of key hazardous situations (EUROCONTROL, 2010, p. 1).

The Roadmap for Airport Surface Movement Safety Nets was designed to increase the coverage of hazardous situations for surface movements and provide direct alerts to flight crews and vehicle drivers (EUROCONTROL, 2010). The surface safety nets cover the complete airport movement areas, including taxiways and aprons, thereby improving safety warnings to allow for effective and timely resolutions of pending aircraft conflicts. EUROCONTROL (2010) found that surface safety nets enhance situational awareness while reducing breakdowns in communications and potential air traffic controller errors.

As the research established, surface safety nets can effectively monitor the distance between aircraft and vehicles on the airport surface area (EUROCONTROL, 2010). Generally, flying aircrafts have limited maneuverability in terms of sudden changes in speed and direction of flight, while maintaining significant freedom in initiating evasive action when necessary to avoid potential conflicts (EUROCONTROL, 2010, p. 7). Comparatively, aircrafts on the ground are more flexible in terms of adjusting the direction and speed of their movement, but are limited to the airport's available taxiways and runways. In this regard, EUROCONTROL (2010) concluded that visibility, airport layout, and available technological systems and procedures all play a significant role in maintaining safety.

EUROCONTROL (2010) further concluded that even though surface safety nets are useful for enhancing safety, the safety function is not independently sufficient and further studies are needed to improve alerting performance within aircraft and control towers (p. 9). Enhanced communication between the safety net function and flight crews is an additional approach with significant potential for increasing airport safety (EUROCONTROL, 2010, p. 9).

EUROCONTROL (2010) found other potential benefits with the implementation of airport surface safety nets included a reduction in the risk of collisions between aircraft and between aircraft and vehicles. Surface safety nets could further reduce the potential damage caused to aircrafts involved in an aircraft, thereby reducing injuries and aircraft damage (EUROCONTROL, 2010). Surface safety nets assist in increasing the efficiency of surface movements and mitigate the risks of operational disruptions. Additional positive outcomes include an increase in the time available to identify actions necessary to avoid a collision by instructing the effected flight crew or vehicle driver (EUROCONTROL, 2010). EUROCONTROL (2010) finally established that automation would effectively assist flight crews by improving their situational awareness and reducing the prospect of detected hazards or operational errors. The researchers acknowledged that future researchers of aircraft operational issues should consider pilot and flight crew input, which would provide increased data to further enhance airport safety (EUROCONTROL, 2010).

Schonefeld and Moller (2012) concluded that even with RIPAS installations, general aviation will still pose an unacceptable risk, affecting runway safety at many airports. As commercial aviation expands into airports used extensively by general aviation aircraft, the risk of runway incursions will likely increase. Although an open question exists regarding the eventual influence of RIPAS (Chapin, 2010), the experience from the deployment of RWSL and FAROS have established that direct visual clues at airports significantly improve an airport's overall runway safety (FAA, 2009).

Schonefeld and Moller (2012) asserted that pilots should have the ability to effectively avoid an inadvertent entry onto an active runway resulting in a runway incursion. Jones and Young (2001) previously identified three significant factors necessary for flight crews to avoid situations that could result in runway incursions. These factors included pilots' constant awareness of the location of their aircraft at an airport, an accurate understanding of the route that the aircraft was directed to travel by ATC, and the ability to effectively detect and correct route deviations (Jones & Young, 2001). An accurate awareness of runway activity was also an influential factor in avoidance of runway incursions (ICAO, 2007; Singh & Meier, 2004).

Consistent with Jones and Young (2001), Schonefeld and Moller (2012) identified three factors that enhanced a pilot's ability to timely detect a potential runway incursion. These factors include an awareness of other traffic in the airport environment, a continuing awareness of the aircraft's location in the airport environment, and the activity status of the operating runway (Schonefeld & Moller, 2012). If these factors are present, the likelihood of a runway incursion decreases significantly (Schonefeld & Moller, 2012).

Surveillance sensors on an airport can also provide relevant and timely information to both the controller and pilot regarding the aircraft's location and its current operating environment (Schonefeld & Moller, 2012). During a series of runway incursion prevention system tests in 2000, the failure of a surveillance system to alert pilots in time to avoid a runway incursion were most often caused by unreliability of the Automatic Dependency Surveillance-Broadcast and Traffic Information Broadcast traffic data (Cassell, 2005; Cassell, Evers, Sleep, & Esche, 2001; Green, 2002; Jones & Young, 2001). These inherent problems were predominantly corrected with the development of RIPAS (Jones & Prinzel, 2011).

Garibay and Young (2013) analyzed airline operational strategies in an effort to reduce general aviation accidents. Because the United States hosts the largest and most diverse general aviation community in the world, these strategies could prove beneficial in reducing the large number of runway incursions happening in the general aviation community (Doquette & Dorr, 2012; General Aviation Manufactures Association, 2010). Compared to general aviation pilots, commercial pilots undergo more frequent training and are required to complete mandated proficiency checks prior to providing services for commercial operators, with most major airline carriers exceeding the minimum currency and training requirements (ALPA, 2011).

Historically, general aviation accident rates have been more frequent than those of the commercial airlines, as commercial flying has been one of the safest modes of transportation, a recognition not shared with general aviation (Abu-Taieh, El Sheikh, & Jafari, 2012; Shetty & Hansman, 2012). Shetty and Hansman (2012) asserted that one possible explanation for this disparity was the difference in operational style between general aviation and commercial airlines. Garibay and Young (2013) contended that it might be possible to improve general aviation safety through the adoption of the best practices utilized by the commercial airlines. This higher level of safety can be explained by the fact that both airline pilots and dispatchers were held jointly responsibility for the safety of every flight (see Aeronautics and Space, 1962; Krause & Jansen, 2014), and were also better organized and had many more resources than general aviation. Because general aviation is composed of a wide range of operations, such as crop-dusting, banner towing, and personal flying (Air Safety Institute, 2010; General Aviation Manufactures Association, 2010), focusing on improving safety protocols in general aviation by determining how general aviation can use airline operational strategies could potentially be helpful in reducing runway incursions and improving aviation safety (Garibay & Young, 2013, p. 2).

Because flight plan quality and flexibility, available resources, as well as governmental regulations are the primary differences between general aviation and commercial operations (Garibay & Young, 2013), general aviation should take specific actions. These actions include (a) embracing in-cockpit technology, which would encourage safer operations and also permit reliable data collection regarding general aviation trends for data-driven decision making; (b) offering incentives for pilots to undergo quality recurrent and safety training, while also eliminating loopholes or shortcuts that compromise safety; and (c) implementing a system of checks and balances to ensure that pilots have a sufficient safety net from human error (Garibay & Young, 2013, p. 15). Garibay and Young (2013) asserted that by incorporating these basic actions into general aviation's flight operations, general aviation's safety record could be improved.

As research continues on the development of aviation safety strategies designed to reduce runway incursions, one of the most promising programs that could improve aviation safety is the FAA's concept of flight operations for the Next Generation Air Transportation System, commonly referred to as NextGen (FAA, 2011a). NextGen is the transition from the current ground-based navigation system to a satellite-based one that relies on the use of a combination of technologies (GAO, 2012b). One of these new technologies would notify pilots at all times of the precise location of other airplanes around them, thereby increasing situational awareness and enhancing safety (McHale, 2010). This enhanced situational awareness would likely be helpful in reducing the number of runway incursions throughout the United States.

Aviation safety literature has pertained to the cause, the potential outcomes of runway incursions, and ways in which runway incursions could be reduced or avoided through new aviation procedures as well as the installation of new safety technology. Government agencies, both foreign and domestic, various aviation stakeholders, and aviation safety researchers have primarily produced aviation literature. Numerous methods to identify probable causes of runway incursions and ways to prevent them have resulted in the development of a number of procedural and technological advancements designed to eliminate or reduce runway incursions at the nation's airports. Continuing research in the areas of runway incursions throughout the world will be helpful in better identifying the causes of runway incursions as well as developing and implementing procedures that are more advanced and technologies that will be beneficial in reducing runway incursions. The research developed from this quantitative dissertation provides needed information to further enhance the FAA's RSP and thereby more effectively reduce runway incursions.

Program Evaluation Methods

Significant in evaluating any government program is the selected program evaluation method (Mertens & Wilson, 2012). Evaluation analyzes a program and its objectives, asks whether these objectives have been achieved, and further identifies the value of continuing the current program or developing a new, more useful one that will better achieve the intended objective of the project (Rossi & Freeman, 1993). Identifying the components of an effective evaluation as well as the potential methods through which it can best be accomplished provides the relevant context that supports the evaluation methodology utilized in this dissertation.

Experts have agreed that an evaluation should not only assess program results, but also identify ways in which to improve the evaluated program (Wholey, Hatry, & Newcomer, 2010). Kirkpatrick and Kirkpatrick (2009) identified different levels of evaluation and how these levels could integrate evaluation data and thereby provide beneficial results to those who might rely on the results. Kirkpatrick and Kirkpatrick (2009) identified four levels of evaluation as (a) Level 1: Reaction, or participant impressions; (b) Level 2: Learning, or learning acquired; (c) Level 3: Behavior, or the application of the learning; and (d) Level 4: Results, or the extent that targeted outcomes occur for the company agency or school system. Utilizing these levels in program analysis would assist in properly analyzing the effect of a program. At the end of a program cycle, the evaluation findings should then be used to determine whether to alter or maintain the program operations (Boulmetis & Dutwin, 2011). The results from this research study provide relevant data that supports the continuance of the FAA RSP but suggest areas in which it could be improved.

Different types of program evaluations entail different outcomes. Evaluations focused on examining and changing processes as they occur are called formative evaluations, whereas evaluations focused on reporting what occurred at the end of the program cycle are called summative evaluations (Boulmetis & Dutwin, 2011, p. 16). Contrary to a formative evaluation, which involves examining a program in progress, a summative evaluation is an assessment of the program's overall effectiveness (Boulmetis & Dutwin, 2011, p. 60). Researchers need to select the appropriate program evaluation method to obtain the desired and relevant information from a program analysis.

The program evaluation of the FAA 2009–2011 RSP is a summative evaluation designed to obtain information regarding the impact of the RSP to effectively reduce runway incursions at the nation's five busiest airports. Since the effectiveness of the RSP is at issue in this dissertation, I reviewed the FAARSP's effectiveness within the context of a summative evaluation. Since each of the five busiest airports in the nation had the latest technological advancements in place during the pendency of 2009–2011 RSP (GAO, 2008b), these airports served as a bellwether for the effectiveness of the FAA's overall RSP. Understanding the relationship between the types, severity, and phase of flight of runway incursions before and after the FAA RSP is helpful in determining if the RSP effectively reduced runway incursions.

When conducting an effective evaluation, a researcher needs to understand both the political and social climate that exists within the government program (Boulmetis & Dutwin, 2011). Several different ways exist through which a program can be structured, including the transactional approach (Rippey, 1973), the goal-free approach (Scriven, 1991), as well as the goal-based evaluation approach (Boulmetis & Dutwin, 2011). Other models that researchers have developed to assist with evaluations include the systems analysis model developed by Rivlin (1971), the art criticism model developed by Eisner (1997), and the adversary model developed by Owens (Madaus, Scriven, & Stufflebeam, 1993).

Rippey (1973) identified the transaction model, which focuses on activity occurring between the evaluator, the participant, and significant project staff. The beneficiaries of this method of evaluation are the clients and practitioners (Boulmetis & Dutwin, 2011, p. 106). This model integrates process evaluation with effective monitoring through a continuous interchange of information between the evaluator and staff, in which the evaluator is an active participant who provides feedback throughout the process (Boulmetis & Dutwin, 2011). The transaction goal-based model meanwhile involves the use of subjectivity, as opposed to objectivity, in its analysis of a program (Boulmetis & Dutwin, 2011).

Scriven (1991) developed the goal-free evaluation model to evaluate a program's actual effect on the needs identified. This evaluation method entails examining the steps a program has taken to address the particularized needs of the client population (Boulmetis & Dutwin, 2011, p. 104). Though the goal-free model is difficult to use for conducting evaluations when the evaluator is part of the program, it is a popular method because a researcher can effectively utilize it in a program with many simultaneously occurring projects (Boulmetis & Dutwin, 2011). After the collection of the data, conclusions are drawn by the evaluator regarding the effect of the program on satisfying the needs of the client (Boulmetis & Dutwin, 2011). When the evaluator is looking at actual effects rather than anticipated effects for which quantitative tools have been designed, the goal-free model is preferable, especially in qualitative evaluations (Boulmetis & Dutwin, 2011).

Alternatively, Provus' (1971) discrepancy evaluation model can be effectively used in situations in which an understanding exists that the program does not work independently but instead is part of a complex organizational structure. When the focus is not to establish a cause-and-effect relationship but instead to only adequately understand the evidence to make reasonable assumptions about cause and effect relationships, this model is most effective (Boulmetis & Dutwin, 2011, p. 102). This model assists in the decision-making process when decisions are based on the difference between present standards and what actually exists (Boulmetis & Dutwin, 2011). The strength of this model lies in the staff being involvement in determining and using the evaluation criteria and standards, which is helpful to program staff who have an evaluator working with them from the beginning of program (Boulmetis & Dutwin, 2011).

Researchers frequently use Madaus, Scriven, and Stufflebeam (1993) decision-making model as a tool to make decisions regarding the future use of a program. With the decision-making model, increased concern exists regarding a program's long-term effects and less with how the program is currently performing (Boulmetis & Dutwin, 2011, p. 107). As such, the decision making model focuses on decisions that will need to be made in the future. The actual methodology used to collect data can vary significantly with both quantitative methods, such as tests and records, and qualitative methods, such as interviews, observations, and surveys utilized for data collection depending on what the sponsor desires to know to make a decision (Boulmetis & Dutwin, 2011). Though researchers can use the decision-making model to structure formative evaluations, they can also use the model effectively for summative evaluations (Boulmetis & Dutwin, 2011).

Meanwhile, the systems analysis model pertains to a program using a systemic method to studying the input, throughput, and output of a program (Boulmetis & Dutwin, 2011, p. 108). This evaluation model is frequently utilized to analyze whether a program is getting individuals through a particular program in an efficient manner, as well as whether the program is achieving its goals (Boulmetis & Dutwin, 2011). Alternatively, with the art criticism model, the evaluator, who is a qualified expert in all aspects of the program, becomes an expert judge on the program's operation (Boulmetis & Dutwin, 2011, p. 108). The evaluator's ability to judge objectively determines the effectiveness of the model. Generally, this evaluation model is employed when a critical review of a program is necessary prior its application for funding or accreditation (Boulmetis & Dutwin, 2011).

Another program evaluation method is the adversary evaluation model, in which the evaluator establishes a jury who will evaluate evidence developed from individuals on particular program aspects (Boulmetis & Dutwin, 2011, p. 109). The jury then judges the evidence using applicable criteria to determine what is actually occurring in the program (Boulmetis & Dutwin, 2011). When differing views exist between clients, staff, community members, or sponsors of what is occurring in a program, this model can effectively resolve the differences (Boulmetis & Dutwin, 2011).

Scriven (1991) described a goal-based evaluation as "any type of evaluation based on and knowledge of—and reference to—the goals and objectives of the program, person, or product" (p. 178). This method, also known as the objective attainment method, is frequently used because of its ease in conducting the program evaluations.

Usually based on stated objectives or goals identified in a proposal, brochure, or other program description, this goal-based evaluation method is not concerned with ancillary items, variables, or occurrences that might be spin-off products of the program activities as opposed to the specifically stated objectives (Boulmetis & Dutwin, 2011, p. 109). In this method, the evaluator seeks to measure specific outcome variables using quantitative or qualitative methods.

Similar to the goal-based model, researchers can effectively utilize the impact-based evaluation model to determine whether a particular program has achieved its desired impact. With most impact evaluations, the researcher seeks to isolate the effects of a particular program to provide decision makers with the ability to determine whether a program should be continued, expanded, or modified (Henry, 2010, p. 125). This model relies on comparative data from before and after the program to determine the program's influence on achieving its stated objectives (Henry, 2010). Rosenbaum and Rubin (1983) and Holland (1986) established the theoretical base for using a comparative group design when analyzing the effect of policy and programs. Researchers have utilized impact evaluations using quantitative estimates between comparative groups when establishing the causal effects of programs (Henry, 2010). More specifically, using an interrupted time-series design is appropriate for longitudinal studies where data exists for before and after the implementation of the program (Henry, 2010).

When evaluating the effect of government-based programs, researchers of comparison group studies have regularly utilized an interrupted time-series design (Biglan, Ary, & Wagenaar, 2000; Bloom, 2003; Bloom & Riccio, 2005; Dee & Jacobs, 2011; Henry & Gordon, 2003; Penfold & Zhang, 2013). Henry and Gordon (2003) utilized an interrupted time-series design when evaluating the effect of a public information campaign designed to reduce air pollution. Biglan, Ary, and Wagenaar (2000) advocated the use of comparison group interrupted time-series experiments when conducting community intervention research. Penfold and Zhang (2013) asserted that the interrupted time-series design worked effectively as a tool for evaluating quality improvement (impact) of a program, especially health care quality improvements. Bloom (2003) provided guidance regarding the effective use of a comparison group interrupted time-series design when measuring the influence of school reform. Dee and Jacob (2011) used a comparison group interrupted time-series design to effectively measure the effect of No Child Left Behind legislation on student achievement. Finally, Bloom and Riccio (2005) utilized a comparison group interrupted time-series analysis to evaluate the effect of an employment program for public housing residents. Using a comparison group interrupted time-series design to evaluate the effect of the FAA RSP is beneficial when seeking to determine the program's impact on the reduction of runway incursions.

In using an impact-based interrupted time-series design, I sought to determine whether the FAA 2009–2011 RSP effectively reduced runway incursions at the nation's five busiest airports. The goal of the FAA RSP was to reduce the number of runway incursions at the nation's airports (FAA, 2008). It accomplished this objective by measuring the specific outcome variables of the RSP. Specifically, it analyzed the types, severity, and phases of flight of runway incursions both before and after the FAA RSP. Understanding the relationship between these variables before and after the RSP is important in assisting decision makers in determining whether the RSP should be modified in future years.

Though a variety of program evaluation methods exist, many evaluators will conduct their evaluations without strictly following any particular model of evaluation and rely on their personally developed evaluation philosophy, plans, and procedures (Worthen, 1990). Ultimately, the value of an evaluation model is premised on its ability to assist evaluators in providing sources of new ideas and techniques, which serves as mental checklists of those things that the evaluator should considered, remember, or be concerned about (Worthen, 1990, p. 46). A model's value as prescriptive guidelines for doing evaluation studies is less significant (Worthen, 1990).

Chapter Summary

Chapter 2 presented the relevant literature available on aviation safety, runway incursions, and government program evaluation literature. Governmental organizations both in the United States and from around the world produced the majority of the aviation safety literature. In the worldwide literature, researchers have universally recognized the global threat posed by runway incursions to aviation safety as a significant problem requiring immediate effective solutions. Struggling with the most effective and efficient ways to solve this problem has been an ongoing debate identified throughout the literature. In the aviation safety literature, researchers consistently described the threats associated with runway incursions but have not identified the best way to predict runway incursions or how best to prevent or reduce their potential risk in the first place. In much of the government, stakeholder, and academic research literature, researchers sought to more fully explain the critical factors associated with runway incursions and identify the best methods through which runway incursions could be effectively reduced through the use of technology, alternative air traffic control procedures and training.

Chapter 3 presents the methodology of this research study, which is premised on the literature review in Chapter 2. I describe the study methodology in this chapter. Chapter 3 also expands the description of the research design and the methods of analysis used in addressing the research question.

Chapter 3: Research Method

Introduction

When evaluating the effectiveness of the FAA 2009–2011 RSP at the five busiest U.S. airports, a summative, impact-based evaluation to analyze runway incursions that happened before and after the implementation of the RSP was appropriate. A summative evaluation entails a focus on the effects or outcomes of a particular project (Rossi, Lipsey, & Freeman, 2004). According to Trochim (2006), a summative evaluation can be divided into several different categories, including outcome evaluations, impact evaluations, cost-effectiveness, cost-benefit analysis, secondary analysis, and meta-analysis. Using an impact-based evaluation, the researcher seeks to determine the effect a program had in achieving its stated goals and objectives (Henry, 2010).

In this study, a summative, impact-based evaluation was the most appropriate method to evaluate the effectiveness of the FAA 2009–2011 RSP because I considered the relationship between the types, severity, and phases of flight of runway incursions that have occurred before and after the implementation of the RSP. Specifically, I sought to determine whether the same types, severity, and phases of flight runway incursions continue to occur after the completion of the 2009–2011 RSP. If so, then the RSP has not reduced the runway incursions at the nation's five busiest airports and has failed to achieve the RSP stated goals and objectives. Alternatively, if positive change occurred in the types, severity, and phases of flight of runway incursions at the nation's five busiest airports after the 2009–2011 RSP, then the program effectively reduced runway incursions at these airports. The conclusions drawn from this study determine whether the

FAA 2009–2011 RSP achieved its targeted impact of reducing runway incursions at the nation’s five busiest airports. If not, decision makers should consider a re-evaluation of the RSP and the consideration of alternative safety methods designed to reduce runway incursions.

The outcome of this impact-based evaluation has a significant determination regarding whether the FAA RSP should continue in its current form. If the RSP has been effective, then further improvements and additional federal funding could be beneficial in further reducing runway incursions at the nation’s five busiest airports. Alternatively, if the RSP has been ineffective at positively changing the types, severity, and phases of flight of runway incursions, then future researchers need to explore alternative safety methods designed to achieve a reduction in runway incursions. The FAA must take the steps necessary to ensure that safety in the NAS is properly maintained (FAA, 2010). This study provided information that could be instrumental in the development of future runway safety programs.

When assessing the effectiveness of the FAA 2009–2011 RSP, a process that compares the runway incursions before and after the program’s implementation was necessary. A comparison group, interrupted time-series design was appropriate for this longitudinal study as data exists that I used to compare the effect of the RSP before and after the implementation of the RSP (Henry, 2010, p. 135). Comparative group design studies are appropriate when analyzing the effect of policy and programs (Holland, 1986; Rosenbaum & Rubin, 1983). Researchers have used impact evaluations when analyzing quantitative estimates between comparative groups to identify the causal effects of a program on variables (Henry, 2010). The FAA data that describes the types, severity, and phases of flight for runway incursions occurring before and after the implementation of the RSP were used for this quantitative analysis, thereby allowing me to assess the effect of the RSP and establishing its effectiveness for reducing runway incursions.

I analyzed all runway incursions occurring at the five busiest U.S. airports for a period of 3 years before the implementation of the program (October 1, 2005 through September 30, 2008) and the 3-year period after the implementation of the program (October 1, 2011, through September 30, 2014). The 3 years during the pendency of the program were excluded from the analysis. Because I focused on the five busiest U.S. airports based upon total passenger boardings and aircraft movements, I analyzed FAA data applicable to these events.

Research Design and Approach

To assess the effectiveness of the FAA's 2009–2011 RSP, a process that compares the runway incursions before and after the RSP's implementation was necessary. To complete this assessment, a comparative group, interrupted time-series design was used to compare data from before and after the completion of the RSP. A comparative group, interrupted time-series design is most appropriate when evaluators wish to assess the effect of programs on their intended outcomes (Henry, 2010; Holland, 1986; Rosenbaum & Rubin, 1983). Comparison group designs represent alternatives to randomized experiments when the goal of the evaluation is to provide a quantitative estimate of the causal effects of a program (Henry, 2010, p. 125). The comparative groups for this study were the runway incursions occurring 3 years before the implementation of the 2009–2011 RSP and those occurring 3 years after the completion of the program. The purpose of most impact evaluations is to isolate the effects of a program to help decision makers decide whether the program should be continued, improved, or expanded (Henry, 2010, p. 125).

I used a comparison group, interrupted time-series design to assess the effect of the FAA 2009–2011 RSP on their goal of reducing runway incursions in regard to the type, severity, and phase of flight of each of the runway incursions. In this study, I conducted a comparison using descriptive statistics of runway incursions occurring before and after the implementation of the FAA 2009–2011 RSP. Descriptive statistics are generally used to numerically describe a group of people, events, work, or other concepts (NcNabb, 2008). A comparison group design provides an alternative to randomized experiments when the goal of the evaluation is to provide a quantitative estimate of the causal effects of a program (Wholey et al., 2010). In this evaluation, the intended outcome was to determine whether the FAA RSP was able to positively change the types, severity, and phases of flight of runway incursions.

Publically available FAA data on all runway incursions throughout the United States occurring between October 1, 2005 and September 30, 2014 was procured directly from the FAA. These data were available and provided by the FAA in an Excel format. The information on each runway incursions includes date and time of occurrence, location (by airport), weather conditions, type of incursion, severity of incursion, aircraft type and category, phase of flight, and narrative description information of each runway incursion. The FAA is the federal government agency charged with identifying, evaluating, and reporting runway incursions occurring in the United States (FAA, 2010).

The FAA has identified and described their source of data in the compilation of runway incursions occurring in the United States. The primary source of runway incursion reports has come from air traffic controllers and pilots (FAA Performance Measure Profile [FPMP], 2013). The data from these runway incursions are recorded in the Comprehensive Electronic Data Analysis Reporting system. Preliminary incident reports are evaluated when received, and evaluations can take up to 90 days to complete (FPMP, 2013). Operations data used to calculate runway incursion rates were provided by OPSNET, which I downloaded directly from the FAA operations and performance data database (FPMP, 2013).

The FAA has addressed the issue of completeness of its runway incursion data. The FAA stated that

> The data are typically not finalized for 90 days following the close of the fiscal year. Surface event reports are reviewed on a daily basis to determine if the incident meets the definition of a runway incursion. Runway incursions are a subset of the incident data collected and the completeness of the data is based on the reporting requirements and completeness for each of the incident types. (FPMP, 2013, p. 2)

The FAA and other agencies have generally used annual runway incursion incident data to provide a statistical basis for research, analysis, and outreach initiatives (FPMP, 2013).

Setting and Sample

The FAA RSP is a national program implemented to reduce runway incursions throughout the United States. Through this study, I focused on runway incursions at the five busiest U.S. airports. All runway incursion data from these five airports for the relevant period of time were analyzed as a part of this study. The five busiest U.S. airports were identified based on total passenger boardings and total aircraft movements for the fiscal year (FAA, 2014c). A passenger boarding occurs when a passenger gets onto an aircraft and departs from that airport (FAA, 1999). An aircraft movement occurs each time an aircraft either lands or takes off from an airport (FAA, 1999). The five busiest airports in relationship to passenger boardings and aircraft movements for calendar years 2011 through 2013 were ATL, ORD, LAX, DFW, and DEN. The passenger boardings and aircraft movements at the five busiest airports represent a significant portion of all passenger boardings and aircraft movements that occur annually in the United States (FAA, 2014c). The implications of runway incursions and FAA efforts to effectively reduce them at these five airports are critical for the overall safety of the NAS.

Addressing Bias

In all research, the potential exists that biases can negatively affect the study's results. As such, researchers should engage in the objective collection of data and seek a fair and impartial interpretation of the results by participating in "reflexivity, which means that the research actively engages in critical self-reflection about his or her potential biases and predispositions" (Johnson, 1997, p. 284). I sought to determine whether the FAA 2009–2011 RSP reduced runway incursions at the nation's five busiest airports. This quantitative study served to answer this question via analysis of the relationship between the types, severity, and phases of flight of runway incursions before and after the implementation of the 2009–2011 RSP at the five busiest U.S. airports.

I used the quantitative data to analyze the relationship between the variables in this study, collected by the FAA. In their collection process, the FAA took steps to ensure the reliability and completeness of their runway incursion data (FPMP, 2013). McNabb (2004) defined archival data research as a way of reviewing published or previously prepared data. Consistent with archival data research, all relevant FAA datasets in this study were already derived, published, and reported in official government records (McNabb, 2004). As such, the risk associated with biased data collection negatively affecting the outcome of the study was less significant than in other types of research (McNabb, 2004).

Maintaining independence in data collection and processing is important. Yin (2008) suggested that the ability of a researcher to remain open to contrary findings can reduce the possibility of the inadvertent introduction of substantial bias into a study (p. 72). In this study, I planned to avoid the introduction of bias by keeping an open mind regarding any potential outcomes, thereby reducing the potential for biases to negatively affect the results of this study.

Data Collection and Analysis

I entered the FAA runway incursion data into SPSS version 22.0 for Windows. These FAA data were collected from runway incursions occurring from October 1, 2005 through September 30, 2014. Institutional Review Board (IRB) approval was granted prior to the start of any research related to data collection. IRB provided the following approval number: 06-24-16-0055329. The runway incursion data generated during the pendency of the 2009–2011 RSP (10/01/2008 through 09/30/2011) were excluded from the dataset. Thus, I only assessed data from 3 years before and 3 years after the 2009–2011 RSP. Only FAA data from the following airports were examined: ATL, ORD, LAX, DFW, and DEN. I conducted descriptive statistics to describe the sample demographics and the research variables used in the analysis. Frequencies and percentages were calculated for nominal data, and means and standard deviations were calculated for continuous data (Howell, 2013).

I screened the runway incursion data for accuracy, missing data, and outliers. The presence of outliers was tested by examination of standardized values. Standardized values represent the number of standard deviations the value is from the mean. Values higher than 3.29 are considered to be outliers and should be removed from the dataset (Tabachnick & Fidell, 2013). Runway incursions with missing data were examined for nonrandom patterns. The study did not include data entries in which a lack of complete major sections existed.

Research Question 1

Is there a relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP?

*H*o1: There is a no relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP.

*H*a1: There is a relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP.

To examine Research Question 1, I conducted a 2x5 chi-square analysis to assess if differences existed between the types of runway incursions that occurred before and after the RSP was implemented. A chi-square analysis is the appropriate analysis to conduct when the goal is to assess the relationship between two nominal variables (Pallant, 2010). In this case, time (pre vs. post) was the nominal independent variable of the analysis. The dependent variable was the type of runway incursion, with levels of operational deviation, operational error, pilot deviation, and vehicle or pedestrian deviation.

Research Question 2

Is there a relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP?

*H*o2: There is no relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP.

*H*a2: There is a relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP.

To examine Research Question 2, I conducted a Mann-Whitney U test to assess if differences existed between the severity of incidents that occurred before and after the FAA implemented the 2009–2011 RSP. A Mann-Whitney U test is the appropriate analysis to be conducted when the goal is to assess if differences exist in an ordinal dependent variable by a dichotomous independent variable (Pallant, 2010). In this case, time (pre vs. post) was the nominal independent variable of the analysis. The dependent variable was the severity of the runway incursion, with levels of Cat. A, Cat. B, Cat. C, and Cat. D; Cat. A as the most severe and Cat. D was the least severe.

Research Question 3

Is there a relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP?

*Ho*3: There is no relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP.

*Ha*3: There is a relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP.

To examine Research Question 3, I conducted a 2x3 chi-square analysis to assess if differences existed between the phases of flight for the runway incursion that occurred before and after the FAA implemented the 2009–2011 RSP. A chi-square analysis is the appropriate analysis to conduct when the goal is to assess the relationship between two nominal variables (Pallant, 2010). In this case, time (pre vs. post) was the nominal independent variable of the analysis. The dependent variable was phase of flight for the runway incursion, with levels of taxiing (TX), take-off (T/O) and landing (LNDG).

Sample Sizes

I conducted a sample size power analysis in G*Power. Examination of the results of the 2x5 chi-square, Mann-Whitney U test, and the 2x3 chi-square followed. Using a medium effect size of .30, an alpha level of .05, and a power of .80, the researcher gathered at least 122 runway incursions to have an appropriate sample size to find significance for a chi-square with four degrees of freedom. The Mann-Whitney U test required 184 runway incursions to find significance. The 2x3 chi-square only required 88 runway incursions. Therefore, I aimed to include 92 runway incursions in each group, before and after the 2009–2011 RSP was implemented. This ensured that significance was achieved for all three tests (Faul, Erdfelder, Buckner, & Lang, 2013).

Instrumentation and Materials

The runway incursion data utilized in this study came directly from the FAA. I analyzed the data through an appropriate quantitative analysis utilizing SPSS 22. The study did not include any other specific instrumentation or materials.

Validity and Reliability

Validity and reliability are important concepts when conducting effective research. In this study, the researcher used FAA archival runway incursion data to compare the types, severity, and phases of flight of runway incursions before and after the implementation of the 2009–2011 RSP at the nation's five busiest airports. According to Frankfort-Nachmias and Nachmias (2008), validity concerns the question of whether the researcher is measuring what he or she intended to measure (p. 149). The data analyzed in this study came directly from archival data collected directly by the FAA during the course of their operations (FPMP, 2013). I did not create or utilize instruments to measure or collect data, but instead relied on the observational data from a federal government agency. As such, issues of validity in this study were not significant.

The FAA has addressed the issue of reliability of its runway incursion data. Reliability concerns whether the researcher included variable errors within the measuring instrument (Frankfort-Nachmias & Nachmias, 2008). As part of the RSP, the FAA utilizes performance data and information collected through a defined, repeatable risk analysis for program management, personnel evaluation, and accountability in prioritizing the FAA facility audits and assessments (FPMP, 2013, p. 2). The FAA verifies and validates the accuracy of its runway incursion data through the initial validation process followed by quality assurance and quality control reviews. The FAA conducts reconciliation of the runway incursion database monthly and explores and resolves any anomalies (FPMP, 2013). If inconsistencies or other problems are identified, the FAA issues a request to re-submit the particular data (FPMP, 2013). Additionally, the FAA conducts annual reviews of reported runway incursion data, which is then compared with data reported from previous years. In this study, the data used in this analysis came directly from the FAA and was not assumed to suffer from measurement error, other than the potential for missing data or unreported cases. As such, the data used in this study was presumably reliable.

Dissemination of Findings

I plan on sharing the findings of this study with the FAA, foreign governments, and other aviation stakeholders who share the goal of effectively reducing runway incursions. In developing the RSP, the FAA considered the interests of many stakeholders (FAA, 2008). Stakeholders have a direct interest in the success of the FAA RSP, which reduces runway incursions and thereby increases the overall safety of the NAS. These stakeholders also have an interest in the outcome of this study, as the results serve to affect future runway safety programs.

I also plan on sharing the findings from this study with other federal government agencies, such as the Department of Transportation, OIG, GAO, NTSB, with an interest in improving aviation safety. The findings will be shared with private organizations that have an interest in the reduction of runway incursions. These organizations include aviation stakeholders, such as Aircraft Owners and Pilots Association, the Experimental Aircraft Association, Air Lines Pilots Association, and National Business Aviation Association.

The Aircraft Owners and Pilots Association and the Experimental Aircraft Association strongly advocate on behalf of general aviation and the pilots who operate primarily general aviation aircraft and work cooperatively with the FAA to ensure the highest levels of safety in all air traffic operations. These organizational stakeholders specifically wish to protect the interests of their pilot members and ensure that the RSP does not impose too many restrictions, which could have a chilling effect on general aviation within the United States. The results of this study may encourage stakeholders to invest in future studies that may help in further reducing runway incursions, not only at the five busiest U.S. airports, but also at smaller general aviation airports located throughout the nation.

The results of this study will also be shared with the major airlines operating at the five busiest airports as well as the airports themselves. The major airlines are interested in ensuring that their share of the costs necessary to support and comply with the provisions of the RSP are not excessive, which would create an additional financial burden during economically challenging times. All of these stakeholders have the ability to modify their policies, practices, and procedures in a manner that will more effectively reduce the potential for runway incursions. Therefore, it is reasonable that these stakeholders will also be interested in the outcome of the evaluation of the effectiveness of the 2009–2011 RSP.

The results of this study are also appropriate for use by the airports identified in this study as well as the local airport unions that advocate for the many employees who perform duties on the airport properties and who could potentially cause a runway incursion. The airports, and the cities that in part fund them, should be concerned regarding the costs associated with reducing runway incursions. The physical modifications or technological improvements necessary to increase aviation safety while minimizing costs are an important consideration when working to effectively and efficiency reduce runway incursions at particular airports.

Employees who perform on or around the airport runways also share a substantial interest in the results of this study. These employees are constantly transferring baggage, cargo, supplies, and other items on and around the airport grounds and in the performance of their duties, must at times cross active runways. Finding ways to reduce runway incursions for this group would have a positive outcome, thus increasing their safety and the safety of the flying public. These employees should also be concerned that because of mandatory requirements of the FAA RSP, their activities and procedures on the airport grounds could be substantially curtailed. Because this group of stakeholders is predominantly interested in accomplishing their assigned duties with the least amount of unnecessary interference, they too should be interested in learning about the results of this study.

Finally, another collective stakeholder with an interest in the success of the FAA RSP is the flying public. Though a nebulous group, the entire FAA safety program is designed to ultimately protect the flying public (FAA, 2010). An overly burdensome program that increases travel times or adds additional governmental fees per trip could have a significant, negative effect on air travel and its costs in the United States. Therefore, this collective stakeholders' input should also be considered when evaluating the potential uses of this particular study. The flying public has a direct interest on the effectiveness of the FAA's runway safety program.

Each of these stakeholders is involved to some degree in the FAA RSP and will be influenced by its success or failure; as such, their input should be given serious consideration when evaluating the results of this study within the context of future program modifications. Each stakeholder shares a direct interest in the results of the study because the outcome could help determine whether the FAA RSP remains in its current form or is modified to achieve a better effect. These stakeholders have worked side-by-side with the FAA in a collaborative effort to promote the goal of aviation safety and in particular the reduction in the number of runway incursions occurring at airports in the United States and around the world.

Chapter Summary

In Chapter 3, I explained the methodology for this quantitative research study. The methodology involved a summative impact-based evaluation using a comparison group interrupted time-series design of the FAA 2009–2011 RSP to determine the effectiveness of the RSP at the five busiest U.S. airports. This chapter included a discussion of the selected research design and approach used to answer the research questions. I also addressed the source of the data used in the analysis, its acquisition method, and the setting and sample sized utilized in this study. Finally, the chapter included a presentation of the statistical methods and procedures implemented as part of the study as well as the dissemination of findings. In Chapter 4, I address the findings and their implications regarding runway incursions, aviation safety, and the FAA RSP.

Chapter 4: Results

Introduction

The purpose of this study was to describe and analyze the type, severity, and phase of flight of runway incursions at the five busiest U.S. airports before and after the 2009-2011 RSP, with the goal of providing information to reduce such occurrences and thereby increase aviation safety within the NAS. In this chapter, I address the following research questions and hypotheses:

RQ1: Is there a relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP?

*H*01: There is a no relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP.

*H*a1: There is a relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP.

RQ2: Is there a relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP?

*H*02: There is no relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP.

*H*a2: There is a relationship between the severity of the runway incursions that occurred before and after the 2009–2011 RSP.

RQ3: Is there a relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP?

*H*03: There is no relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP.

*H*a3: There is a relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP.

This chapter begins with a description of the data collection process, the preanalysis data cleaning, as well as descriptive statistics followed by a summary of the results. Following this is a detailed analysis of the results and a brief chapter summary.

Data Collection

I collected the FAA data from runway incursions occurring from October 1, 2005 through September 30, 2014. The dataset did not include runway incursion data generated during the pendency of the 2009–2011 RSP (10/01/2008 through 09/30/2011). Thus, the data collection only involved data from 3 years before (10/01/2005 through 09/30/2008) and 3 years after (10/01/2011 through 09/30/2014) the 2009–2011 RSP. I only analyzed FAA data from five airports: ATL, ORD, LAX, DFW, and DEN. This data collection process did not vary from the process stated in Chapter 3.

Preanalysis Data Cleaning

The original dataset consisted of 8,196 cases. I assessed these for inclusion criteria: occurring 3 years before or after the 2009–2011 RSP and occurring at the ATL, ORD, LAX, DFW, or DEN airports. I removed a total of 1,133 cases for not meeting the date requirement and removed a total of 6,639 cases for not meeting the location requirement. The analysis then involved an assessment of outliers using the guidelines put forth by Tabachnick and Fidell (2013). I created standardized scores and removed any cases falling outside of ±3.29 standard deviations, considered outliers. A total of 13 cases were removed as outliers, which consequently removed the entire potential Cat. A incursions from the data. This left a final dataset of 411 cases for analyses.

Table 2

Frequencies and Percentages of Type, Severity, and Phase of Incursion

Variable	*n*	%
Type		
OD	0	0.0
OE	61	14.8
OTH	67	16.3
PD	200	48.7
V/PD	83	20.2
Severity		
Cat A	0	0.0
Cat B	7	1.7
Cat C	176	42.8
Cat D	137	33.3
N/A	91	22.1
Phase		
Taxi	259	63.0
Takeoff	42	10.2
Landing	69	16.8
N/A	41	10.0

Note. Percentages may not equal 100% due to rounding error.

Descriptive Statistics

Of the final 411 cases, a large proportion were classified as PD (n = 200, 48.70%). Lesser amounts were classified as OE (n = 61, 14.8%), OTH (n = 67, 16.3%), or V/PD (n = 83, 20.2%). Most occurred during the taxiing phase (n = 259, 63.00%), although 10.2% occurred during takeoff, 16.8% occurred during landing, and 10.0% did not apply to the allotted categories. The most frequently reported severity level was Cat. C (n = 176, 42.80%), with none in Cat. A, 1.7% in Cat. B, and 33.3% in Cat. D. Aside from these categories, 22.1% did not fall into the allotted categories. Table 2 presents all frequencies and deviations.

Summary of Findings

I assessed results of the analyses of Research Questions 1, 2, and 3 in terms of the chi-square and Mann-Whitney U tests used to answer these questions. The chi-square analysis used to answer Research Question 1 indicated a statistically significant relationship between the type of incursion and time of occurrence, where more total incursions were reported postprogram. However, fewer OE type incursions occurred postprogram and slightly fewer V/PD type incursions occurred postprogram. The Mann-Whitney U analysis used to test Research Question 2 identified a statistically significant difference in severity of runway incursions based on whether incursions were taken from a group before or after the 2009–2011 RSP, with higher severity before the 2009-2011 RSP. The final chi-square analysis conducted on Research Question 3 indicated that there was no statistically significant relationship between the phase of flight of the runway incursions and time of the program.

External Validity

To assess external validity of the sample, I compared demographics of the sample to those of the population. For the type of runway incursion, PD represented the highest number of incursions (63.4%). V/PD (24.2%) was the second highest type of incursion, followed by OE (5.2%) and OTH (7.2%). The severity of the incursions from the sample was slightly different from the population with Cat. D (62.4%) having more than Cat. C (36.7%), but Cat. B (0.9%) still shows the least amount of incursions. Finally, the phase of flight of the runway incursions was also similar to those from the population. Specifically, TX (63.5%) had the highest percentage, followed by LNDG (20.9%) and T/O (15.6%). Overall, the sample was representative of the population.

Results

Research Question 1

I conducted a 2x5 chi-square test of independence to examine whether runway incursion type and time of program were independent. Two levels in time existed: preprogram and postprogram. Five levels in type of runway incursion existed: V/PD, PD, OTH, OE, and OD. Prior to conducting the analysis, I assessed the assumption of adequate cell size, which requires all cells to have expected values higher than 0 and 80% of cells to have expected values of at least five (Howell, 2013). All cells had expected values higher than 0, indicating the first condition was met. A total of 100% of the cells had expected frequencies of at least five, indicating the second condition was met.

The overall results of the chi-square test were significant, $\chi^2(4) = 104.07$, $p < .001$, indicating that a significant relationship existed between the type of runway incursions preprogram verses postprogram (time). As such, the null hypothesis for Research Question 1 was rejected. Overall, more total incursions were reported postprogram (*n* = 232, 56.40%) than preprogram (*n* = 179, 43.60%). However, fewer OE type incursions occurred postprogram (*n* = 8, 1.90%) when compared to preprogram (*n* = 53, 12.90%), and slightly fewer V/PD type incursions occurred postprogram (*n* = 46, 11.20%) versus preprogram (*n* = 37, 9.00%). Therefore, significantly fewer OE and V/PD incursions occurred, but significantly more PD (*n* = 120, 29.20%) and OTH (*n* = 67, 16.3%) incursions occurred after the program. Table 3 presents the results of this analysis.

Table 3

Results of the Chi-Square Analysis Comparing Type of Incursion by Time of Occurrence

	Time			
	Pre-program		Post-program	
Type	*n*	% of total	*n*	% of total
OE	53	12.9	8	1.9
OTH	0	0.0	67	16.3
PD	80	19.5	120	29.2
V/PD	46	11.2	37	9.0
OD	0	0.0	0	0.0
Total	179	43.6	232	56.4

Note. $\chi^2(4) = 104.07$, $p < .001$.

Research Question 2

I conducted a Mann-Whitney U two-sample rank-sum test to examine whether significant differences existed in the severity of runway incursions before and after the 2009–2011 RSP. The Mann-Whitney U two-sample rank-sum test is a nonparametric alternative to the independent samples *t*-test and does not share the independent samples *t*-test's distributional assumptions (Lehmann, 2006). In all, I gathered 128 observations in Group 1 (preprogram), 192 observations in Group 2 (postprogram), and 91 classified as NA. The results of the Mann-Whitney U Test were significant, U = 15091.5, $z = -3.98$, $p < .001$. The mean rank for Group 1 was 182.40, and the mean rank for Group 2 was 145.90. The distribution of the severity of runway incursions for Group 1 was significantly different from the distribution of the severity of runway incursions for Group 2. The severity of the runway incursions was significantly lower postprogram than it was preprogram. Table 4 presents the results of the Mann-Whitney U Test.

Table 4

Mann-Whitney U Test for Severity of Runway Incursion by Time of Occurrence

	1	2			
Variable	*Mean Rank*	*Mean Rank*	U	*z*	*p*
Severity	182.40	145.90	15091.5	-3.98	< .001

Research Question 3

I conducted a 2x3 chi-square test of independence to examine the relationship of phase of flight of the runway incursions and time of the program. The two levels in time were preprogram and postprogram. The three levels in phase of flight of the runway incursions were taxiing (TX), take-off (T/O), and landing (LNDG). Prior to conducting the analysis, I assessed the assumption of adequate cell size, which requires all cells to have expected values higher than 0 and 80% of cells to have expected values of at least five (Howell, 2013). All cells had expected values higher than 0, indicating the first condition was met. A total of 100% of the cells had expected frequencies of at least five, indicating the second condition was also met.

The results of the chi-square test were not significant, $\chi^2(2) = 4.67$, $p = .097$, suggesting that independence could not be ruled out as an explanatory mechanism for the relationship between phase of flight of the runway incursions and time (preprogram verses postprogram) of the RSP. The observed frequencies were not significantly different from the expected frequencies. As such, the null hypothesis for Research Question 3 could not be rejected. Table 5 presents the results of the chi-square test for Research Question 3.

Table 5

Results of the Chi-Square Analysis Comparing Phase of Flight and Time of Occurrence

	Time			
	Pre-program		Post-program	
Flight Phase	*n*	% of total	*n*	% of total
Taxiing	108	29.2	151	40.8
Takeoff	25	6.8	17	4.6
Landing	31	8.4	38	10.3
Total	164	44.3	206	55.7

Note. $\chi^2(2) = 4.67$, $p = .097$.

Chapter Summary

This chapter included descriptive statistics along with a summary and a detailed analysis of the results for each of the research questions in this study. To assess Research Question 1, I performed a chi-square analysis and found it to be significant. The results of this analysis suggested a significant relationship between the types of runway incursions occurring preprogram and postprogram. I further established that significantly more runway incursions occurred postprogram compared to preprogram. To assess Research Question 2, I performed a Mann-Whitney U test, and I found that a significant difference existed between preprogram and postprogram severity of runway incursions. To assess Research Question 3, I performed a second chi-square analysis and found it to be not significant. No statistically significant association existed between the phases of flight of the runway incursions preprogram verses postprogram.

The next chapter includes a discussion of these findings and their interpretations in the context of this study and existing literature. I address implications for social change, recommendations for action, and recommendations for future research studies in the area of runway incursions and aviation safety.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

Through this study, I focused on determining the effectiveness of the FAA 2009–2011 RSP at the nation's five busiest airports. Runway incursions have been an increasing threat because of projected increases in air traffic within the United States and throughout the world (FAA, 2015). The FAA designed the RSP for the purpose of reducing runway incursions and increasing aviation safety throughout the NAS (FAA, 2002, 2008). Whether the FAA RSP has been effectively reducing runway incursion was a question that needed to be answered. I answered this question by comparing the types, severity, and phase of flight of runway incursions from 3 years before and after the RSP at the nation's five busiest airports. Through this quantitative study, I sought to draw a correlation between runway incursions' type, severity, and phase of flight at these five airports preprogram versus postprogram, thus providing a more focused picture of the effect of the FAA 2009–2011 RSP.

I explored the following research questions: (a) is there a relationship between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP? (b) is there a relationship between the severity of runway incursions before and after the 2009–2011 RSP? and (c) is there a relationship between the phase of flight when the runway incursion occurred before and after the 2009–2011 RSP? Several key findings emerged from this study. The first finding was that a significant relationship existed between the types of runway incursions that occur on the runway before and after the 2009–2011 RSP. The second finding was that significant differences existed between the severity of runway incursions that occurred before verses after the 2009–2011 RSP. Lastly, no statistically significant relationship existed between the phases of flight when the runway incursions occurred before and after the RSP.

This study filled a gap in the literature associated with runway incursions because I analyzed runway incursions from more than just a numerical perspective. Instead, I considered runway incursions regarding the type, severity, and when, during the phase of flight, the runway incursion occurred. Because of this study, an improved understanding exists regarding the relationships between these variables. Additionally, I established a more detailed picture of the effect of the FAA 2009–2011 RSP, which can assist decision makers in modifying the RSP to enhance its overall effectiveness.

Consistent with the underlying theoretical base, the use of a comparative group (Holland, 1986; Rosenbaum & Rubin, 1983), interrupted time-series design (Henry, 2010) helped to analyze the runway incursion data in a manner that allowed me to answer the research questions. I highlight the causal results (impact) that the FAA 2009–2011 RSP had on reducing runway incursions and increasing aviation safety within the NAS.

In previous runway incursion and aviation safety literature, researchers predominately studied runway incursions by categorizing these instances into their component parts and then analyzing these parts to better understand their relationship to one another as well as seeking methods to reduce their number and severity. Governmental organizations, aviation stakeholders, and academics have attempted to discuss runway incursions in terms of their inherent risk to the NAS. These researchers explored communication problems (Australian Transport Safety Bureau, 2004) and focused on human factors (Chang & Wong, 2012; Rantanen et al., 2006) as well as organizational structures issues (Adam et al., 2002; ICAO, 2002; Rogerson & Lambert, 2012) to develop recommendations useful for reducing runway incursions. Other researchers have studied the best technological advancements that can be introduced at airports and used by pilots to enhance safety (Horowitz & Santos, 2009; Schonefeld & Moller, 2012), such as RIPAS and RIAAS (NASA, 2005), which would assist in decreasing the number of runway incursions and their precursor events (Schonefeld & Moller, 2012). The FAA (2009) has also emphasized the importance of timely implementation of runway safety-enhancing technologies (ASDE-X, FAROS, and RWSL), at the nation's five busiest airports as well as a number of other airports throughout the country.

The findings resulting from this research study supplement the existing literature and provide increased insights into which methods implemented by the FAA have had the most significant effect at reducing runway incursions. The results of this study will help FAA decision makers and other stakeholders establish a deeper understanding of the effectiveness of technological and other methods for reducing runway incursions. This knowledge will assist those charged with improving aviation safety throughout the world to improve their aviation safety programs. Ensuring that aviation is globally safer for all the flying public and the many others in the aviation industry will increase aviation operations worldwide and thereby encourage positive social change. As public administrators work to create and improve policies designed to enhance aviation safety for the public (Lowi et al., 2015), the results of this research study allow these administrators to focus their attention on those methods that will most likely have the most significant effect on improving aviation safety in the NAS and throughout the world.

Interpretation of Findings

This research study's findings and resulting interpretations are important when considering how to improve the FAA RSP in future years. All aviation safety stakeholders must work collaboratively to reduce runway incursions throughout the world. Though this study only pertained to runway incursions at the five busiest U.S. airports, the results are applicable to airports throughout the world and provide a deeper understanding of which methods most effectively reduce runway incursions. Through collaborative efforts, aviation safety stakeholders can work to develop methods, techniques, and procedures that will have the most significant influence on reducing the frequency and severity of runway incursions.

Before discussing each of the research questions in this study, understanding the descriptive statistics relating to the final dataset of 411 cases used in the analysis was important. The total number of runway incursions at the nation's five busiest airports increased from 179 (preprogram) to 232 (postprogram). If a positive effect had resulted from the implementation of technological advances and improvements designed to reduce runway incursions at the nations' five busiest airports, a reduction in the total number of runway incursions would have been expected. The fact that more runway incursions are happening after the RSP is of concern and requires a deeper inquiry into the underlying nature and circumstances of these incursions.

Research Question 1

Research Question 1 addressed the relationship between the types of runway incursions occurring before and after the FAA 2009–2011 RSP. I analyzed five types of runway incursion: V/PD, PD, OE, OD, and OTH. If the RSP had been effective at reducing runway incursions, a difference in the types of runway incursions would be expected. Additionally, analyzing the numbers of different types of runway incursions before and after the RSP provides insights into any influence the RSP had on reducing these types of runway incursions preprogram verses postprogram.

The chi-square analysis used to answer Research Question 1 determined that a significant relationship existed between the types of runway incursions occurring before and after the RSP. The overall results of the chi-square test were significant, $\chi^2(4) = 104.07$, $p < .001$, indicating that a relationship existed between the types of runway incursions preprogram verses postprogram existed. Although the overall number of runway incursions increased preprogram to postprogram, fewer OE type incursions occurred postprogram (n = 8, 1.9%) when compared to preprogram (n = 53, 12.9%). Table 3 from Chapter 4 presents the full breakdown of Research Question 1 results from the chi-square analysis comparing the type of incursion and time of its occurrence. The fact that a reduction in OE (air traffic controller errors) occurred, while a corresponding increase in the total number of runway incursions postprogram was significant, suggests that the methods implemented by the RSP to reduce this type of runway incursion are having a positive effect on reducing runway incursions at the nation's five busiest airports.

Runway incursions are fairly frequent as a topic within the larger body of knowledge regarding flight safety literature (Australian Transport Safety Bureau, 2004; Horowitz & Santos, 2009; ICAO, 2002). Researchers have concluded that major airports in the United States operate with unacceptable levels of risk because of their inherent potential for runway incursions and their failure to adequately address these safety concerns (ALPA, 2007; NTSB, 2010). This is partly why the FAA adopted the RSP as a means of diminishing instances of runway incursions (Skorupski, 2010). Because of the significant exposure that could result from an aviation accident, safety has remained an essential component in air transportation (Skorupski, 2010). As a part of the RSP, the FAA amended Code of Federal Regulations §91.129(i), requiring that all aircraft runway crossings be authorized only by ATC instructions or clearances (NTSB, 2000). The FAA also modified FAA Order 7110.65, which changed ATC procedures that required aircrafts crossing multiple runways to be issued ATC crossing instructions for each runway after the aircraft crossed the previous runway (NTSB, 2000, p. 16). These changes have had a positive influence in reducing OE at the five busiest airports in the nation and should be continued as it appears to be having a positive influence on reducing this type of runway incursion. Consistent with the reduction in OE type of runway incursions, the V/PD type of incursion also decreased from 11.2% (46 events) to 9.0% (37 events). This result was another positive indicator that the RSP has had a positive effective on reducing this type of runway incursions. The methods used by the RSP to help in the reduction of V/PD type of incursions should also be emphasized because it appears to be producing the desired outcome.

However, the number of PD and OTH type of runway incursions increased significantly. This was supported by Schonefeld and Moller (2012), who asserted that even with RIPAS installations, there will still be risks to runway safety at various airports. Schonefeld and Moller (2012) reported that due to the expansion of commercial aviation into general aviation airports, the risk of runway incursions will continue to increase. This was seen within the current study, wherein the number of PD type of runway incursion increased by 9.7%, from 19.5 % (80 events) preprograms to 29.2% (120 events) postprogram. This finding is significant in that the methods used by the RSP to reduce the number of PD type runway incursions are not effectively working. This finding contradicts the findings of Jones and Young (2001), who posited that by being aware of the aircraft at an airport, having an accurate understanding of the route aircraft was directed to travel by ATC, and having the ability to effectively detect and correct route deviation, the RSP can assist pilots in avoiding runway incursions. These methods, which include educating, training, and establishing new procedures, do not appear to be reducing these type of runway incursions at the nation's five business airports. As a larger number of less qualified pilots access these airports with the projected increase in aviation operations (FAA, 2015), the threat posed by PD type of runway incursions will likely increase significantly.

Also of concern is the fact that the OTH type of runway incursions has increased by 16.3%. A deeper understanding and analysis of these OTH types of runway incursions would be helpful in assisting the FAA with improving its RSP. Future researchers should consider exploring this phenomenon and provide information to the FAA and other aviation safety stakeholders. The FAA will need to determine what can be changed within the RSP to increase the effect of the RSP and reduce these types of runway incursions. Previous to the establishment of the RSP, it was determined that runway incursions were most often caused by unreliability within the Automatic Dependency Surveillance-Broadcast and Traffic Information Broadcast traffic data (Cassell, 2005; Green, 2002; Jones & Young, 2001); however, the development of RSP was believed to be the correction to these problems (Jones & Prinzel, 2011). Rather, it has been established that even with the implementation of RSP, there are still outlying problems with runway incursions.

According to the results emerging from the analysis of Research Question 1, there was a significant relationship between the types of runway incursions occurring preprogram and postprogram. The RSP has not changed the types of runway incursions occurring at the nation’s five busiest airports. If the RSP had a positive effect on these types of runway incursions, significant differences between preprogram and postprogram RSP samples would be expected. The fact that this change did not occur is concerning and suggests that the FAA needs to improve its RSP.

Research Question 2

Research Question 2 addressed the relationship between the severities of the runway incursions occurring before and after the FAA 2009–2011 RSP. The results of this test showed that no statistically significantly relationship existed between the severity of the nature of runway incursions that occurred before the implementation of the RSP and those that occurred after the RSP.

Group 1 had 128 observations (preprogram), and Group 2 had 192 observations (postprogram). In addition, 91 observations were classified as NA. The results of the Mann-Whitney U test were significant, U = 15091.5, $z = -3.98$, $p < .001$. The mean rank for Group 1 was 182.40, and the mean rank for Group 2 was 145.90. The distribution of the severity of runway incursions for Group 1 was significantly different from the distribution of the severity of runway incursions for Group 2. The severity of the runway incursions was significantly lower postprogram than it was preprogram. The RSP has been effective in reducing the most severe of runway incursions at the nation's five busiest airports. See Table 4 in Chapter 4 for the results of the Mann-Whitney U test for the severity of runway incursions by time of occurrence.

The fact that the severity of the runway incursions for Group 1 was significantly different than the distribution for Group 2 is positive. One of the goals of the FAA RSP was to reduce the severity of the runway incursions from the more severe, Cat. A, to the less severe, Cat. D (FAA, 2008). The RSP has been successful in reducing the severity of runway incursions at the nation's five busiest airports. All 13 of the Cat. A incursions were removed as outliers from the dataset, because they fell outside ±3.29 standard deviations (Tabachnick & Fidell, 2013). The FAA 2009–2011 RSP has been effective at reducing the severity of runway incursions at the nation's five busiest airports. This is similar to the assertions of Schonefeld and Moller (2012) who purported that if RIPAS was to theoretically succeed, there would be a decrease in the number of runway incursions and the events leading to a potential runway incursion; but, a corresponding decrease in the severity of the runway incursion should also occur.

Managing risk and safety effectively is a practical problem, which has historically been addressed by examining the underlying causes of incidents and accidents, identifying the risks associated with them, and then determining appropriate safety standards consistent with socially acceptable values (Skorupski, 2010). Although I found that there was not a decrease in the number of runway incursions, there was a decrease in the severity of the reported runway incursions. This is because aircraft traffic relies on human decision-making, which can be disastrous if adequate information is not conveyed in time to the pilots (Schonefeld & Moller, 2012). With the quality of information enhanced through technology, poor decisions can be minimized, thereby reducing the severity of runway incursions (Schonefeld & Moller, 2012).

Research Question 3

Research Question 3 addressed the relationship between the phase of flight of runway incursions occurring before and after the FAA 2009–2011 RSP. I analyzed TX, T/O, and LNDG preprogram verses postprogram in this chi-square analysis. The results of this test were not significant, $\chi^2(2) = 4.67$, $p = .097$, suggesting that independence cannot be ruled out as an explanation for the relationship between phase of flight of the runway incursions and time (preprogram v. postprogram) of the RSP. The observed frequencies were not significantly different from the expected frequencies. See Table 5 in Chapter 4, which identifies the results of the chi-square analysis comparing phase of flight and time of the occurrence.

The taxiing phase of flight for postprogram runway incursions increased from the preprogram occurrences by 12.6%. Before the RSP, 108 (29.2%) runway incursions occurred during the taxiing phase of flight and 151 (40.8%) occurred after the RSP. The fact that a higher percentage of the runway incursions happened during the taxiing phase of the flight is a positive indicator that the RSP had a beneficial influence on reducing runway incursions. When runway incursions occur during the taxiing phase of a flight operation, an increased likelihood exists that any resulting injuries will be less severe and any resulting damage will be less substantial because lower speeds exist at the time of the impact. The number of runway incursions happening during the landing phase increased from 31 (8.4%) preprogram to 38 (10.3%) postprogram. Although the increase in total number of runway incursions occurring during the taxiing phase was a positive indicator and suggested an improvement in aviation safety, an increase in the number of incursions happening during the landing phase suggested a higher threat to aviation safety and increased risk to the flying public.

On a positive note, a decrease occurred in the number of runway incursions happening during the takeoff phase of the flight. The results showed 25 (6.8%) preprogram runway incursions during the takeoff phase, compare to 17 (4.6%) postprogram. Because the takeoff phase of flight includes aircrafts operating at high rates of speed, a reduction of runway incursions during this critical phase of flight is significant. This result also suggests that the RSP has positively reduced runway incursions at the nation’s five busiest airports. It should be noted that the results of Research Question 3 did not have any relation to the previous findings reported within Chapter 2. An additional search of the preexisting literature also indicated that phase of flight and runway incursions occurring before and after the FAA 2009–2011 RSP, including taxiing and landing, were not accounted for by previous researchers, indicating a need for further study in regards to runway incursions and phase of flight. This is necessary research that must be undertaken given the enormous risk that accompanies runway incursions during takeoff and landing, wherein pilots are often responsible not only for highly complex pieces of machinery, but also human lives.

In conclusion, the collective results from the three research questions established that the FAA 2009–2011 RSP had some influence in effectively reducing runway incursions at the nation's five busiest airports, but modifications need to occur to help improve the program's overall reduction of runway incursions. The results from Research Question 1 raise concerns in light of the fact that the analysis determined a significant relationship existed between the types of runway incursions occurring before and after the RSP. Though OE and V/PD types of incursions decreased, a significant increase existed in the number of PD types of runway incursions postprogram. A substantial increase in the number of pilot deviations resulting in runway incursions is serious and does not suggest that the RSP has effectively reduced runway incursions at the nation's five busiest airports. Even though the findings establish a positive influence on reducing the severity of runway incursions, as well as a positive movement in the phase of flight from more hazardous to less hazardous, the significant correlation between the preprogram and postprogram types of runway incursions is of significant concern. These findings suggest that the FAA needs to modify the RSP to focus more of its attention on reducing the number of pilot deviations.

The primary research question presented in this research study was whether the FAA 2009–2011 RSP has effectively reduced runway incursions at the nation's five busiest airports. Based on the research findings and their relevant interpretations, the ultimate finding is that the FAA 2009–2011 RSP has not effectively reduced runway incursions at the nation's five busiest airports. The FAA needs to re-evaluate its RSP and explore additional ways to increase its overall influence, especially as it relates to reducing the number of runway incursions resulting from pilot deviations.

Implications for Social Change

The results of this research study have significant implications for positive social change locally, nationally and internationally. Though the FAA 2009–2011 has made some progress in effectively reducing runway incursions at the nation's five busiest airports, the RSP has not effectively reduced runway incursions since the same types of runway incursions are occurring preprogram as compared to postprogram. Improving the RSP to address the increasing threat of pilot deviations resulting in runway incursions and negatively affecting aviation safety is a significant concern that needs to be appropriately addressed to ensure the highest levels of aviation safety within the NAS. The findings from this study will have important influences on constructive modifications of the RSP, thereby substantially increasing aviation safety for all members of society and encouraging positive social change throughout the world.

On a local level, fewer runway incursions translate into less aircraft accidents on the many airports throughout the nation. A reduced number of aircraft accidents mean a safer working environment for airport employees and the many others who rely upon it for a living. Though the nature of aviation has historically presented significant safety risks (FAA Flight Standards Service, 2012) and continues to be one of the most substantial risks that jeopardize aviation safety within the NAS (FAA, 2014d), reducing runway incursions and thereby decreasing the inherent safety risks associated with aviation directly benefits society.

A safer aviation environment will promote industrial growth throughout the world during the next several decades (FAA, 2015). As growth in aviation operations occur, the potential risk of a runway incursion also increases (FAA, 2013a). As larger numbers of people travel, both nationally and internationally, keeping these individuals safe is of primary importance for all governments (Lowi et al., 2015) as well as aviation stakeholders. With enhanced aviation safety, the overall costs of traveling decrease, which allows more people to travel by air and thereby stimulates the world's economies by providing new opportunities for those employed or otherwise connected with the aviation industry (Air Transportation Action Group, 2014). Reducing the potential for runway incursions and enhancing aviation safety will help improve the inherent safety of air traffic operations throughout the world (FAA, 2014d).

Higher levels of safety will positively stimulate the growth of aviation activities, resulting in further economic expansion, thereby benefiting many individuals and developing countries worldwide. Improving the quality of life for members of a society through means of social, political, and economic modification supports positive social change. Developing a vibrant air traffic system within a country can have a positive influence strengthening the infrastructure of a nation as well as helping maintain a more resilient economy (Air Transportation Action Group, 2016).

The FAA will use the findings from this study to successfully modify their RSP so that the program's resources can be more efficiently allocated for the purpose of effectively reducing runway incursions not only at the five busiest U.S. airports, but also throughout the world. Improving aviation safety through the reduction of runway incursions and thereby increasing the inherent safety of aviation worldwide will result in positive social change for everyone.

Recommendations for Action

Since the inception of the RSP in 2002, the FAA has focused its attention on reducing the number and severity of runway incursion within the United States (FAA, 2008). Historically, air traffic accidents are generally a combination of different interrelated factors (Skorupski, 2010). How best to address this combination of factors that lead to runway incursions is a question that the FAA has struggled with when creating and subsequently modifying their RSP.

The findings from this research study established that the RSP has made some limited progress in achieving its safety goals and objectives, but needs to do more to effectively reduce runway incursions at the five busiest airports in the nation. This section addresses several recommendations for action within the context of this study, which could prove beneficial in the attainment of the FAA's specified goals and objective for the RSP. While I viewed the FAA RSP in a theoretical context, it was determined that, theoretically, RSP is not as successful as it potentially could be, but is a step in the right direction. This was determined within Research Question 3, wherein I determined that the FAA RSP has not worked effectively to reduce runway incursions during the landing phase. Instead, it was reported that runway incursions during the landing phase of flight actually increased 31 to 38, demonstrating a 1.9% increase. This is especially troubling given the fact that an increase in the number of incursions happening during the landing phase suggests a greater threat to aviation safety and increased risk to the flying public.

The FAA needs to reevaluate the way in which the RSP works to reduce runway incursions at the nation's five busiest airports and throughout the country. Several of these recommendations to improve the RSP are consistent with previous recommendations from organizations, such as the OIG and NTSB. In light of the increased number of pilot deviations resulting in runway incursions, the FAA should promote increased voluntary pilot participation in the Runway Incursion Information Evaluation Program (OIG, 2010). To date, the FAA has not taken an active lead in promoting the Runway Incursion Information Evaluation Program to pilots in order to collect and analyze more data to identify and mitigate runway incursion causal factors (OIG, 2010). If pilots are not encouraged to participate in these types of programs, the data necessary to establish a stronger connection with causal factors influencing is missing in the effort to reduce runway incursions.

The FAA needs to focus on the three factors that enhance a pilot's ability to timely detect a potential runway incursion, which are an awareness of other traffic in the airport environment, a continuing awareness of the aircraft's location in the airport environment, and the activity status of the operating runway (Jones & Young, 2001;

Schonefeld & Moller, 2012). Providing additional training and education to pilots is important if the FAA is going to effectively reduce runway incursions resulting from pilot deviations.

Also important is increased collaboration with the airline communities to establish a process whereby regional RSP managers would receive access to internal data on runway incursions and surface incidents, which will aid in identifying trends, underlying reasons, and possible local solutions to runway incursions. These solutions can be shared with other aviation safety stakeholders. Sharing local best practices successful in reducing runway incursions elsewhere throughout the NAS would be helpful in promoting enhanced aviation safety.

The FAA may also wish to implement increased training requirements for pilots desiring to conduct flight operations at a particular airport. During this enhanced training and consistent with an earlier OIG recommendation (OIG, 2010), the FAA should require a safety risk analysis to evaluate existing operational procedures at those airports where the FAA has identified potential runway safety risks. Consistent with the OIG's recommendation (OIG, 2010), emphasis must be placed on increased collaboration between aviation industry stakeholders and encourage shared safety risk analysis. By promoting this approach, all the stakeholders share a common goal of working to reduce runway incursions at the nation's airports. Ideally, this type of collaborative relationship will have a positive effect on reducing the number of runway incursions resulting from pilot deviations.

With an increase in the number of taxiing related runway incursions, the FAA needs to take steps to minimize these risks. Previously, the GAO (2009) emphasized that the FAA should increase aviation oversight, especially of runway and ramp areas, through improved aviation safety data. As part of their recommendations, the GAO (2000) suggested implementing existing and current technologies while providing incentives for the acquisition of the latest technologies for airlines as well as enhancing runways and more effectively using advantages of NextGen technologies.

The FAA also needs to focus attention on reducing runway incursions through the effective deployment of technological advancements, such as RIPAS and RIAAS (NASA, 2005). These systems will assist pilots and others in avoiding runway incursions by providing them early warnings designed to avoid the events leading up to an incursion. Other researchers (Horowitz & Santos, 2009; Schonefeld & Moller, 2012) support the continued deployment of technological advancements throughout the NAS. These technological advancements would help provide operational information, while avoiding poor decisions that could lead to runway incursions. The FAA (2009) has previously expressed an interest in further developing and deploying runway safety-enhancing technologies (ASDE-X, FAROS, and RWSL), but needs to do much more in this area, especially as air traffic within the NAS increases.

When considering the best ways to reduce runway incursions throughout the nation, the FAA needs to pay special attention to general aviation pilots to avoid runway incursions. The findings from this research study demonstrate that pilot deviations resulting in runway incursions are a significant aviation safety concern. Compared to general aviation pilots, commercial pilots undergo more frequent training and are required to complete mandated proficiency checks prior to providing services for commercial operators, with most major airline carriers exceeding the minimum currency and training requirements (ALPA, 2011). In light of the findings of this research study, setting new training requirements for pilots especially regarding runway incursions should be a focus for the FAA as they reevaluate their RSP.

The FAA needs to continue its training programs for its air traffic controllers, which have resulted in a decrease in the number of operational errors previously occurring at the airports. Those methods designed to assist pilots also need to be enhanced. The FAA needs to focus on educating and training pilots. This education must be taken through the FAA and by all stakeholders, such as the airlines. The FAA must also encourage aviation safety stakeholders to work collaboratively to reduce runway incursions throughout the world. Increased cooperation with ICAO and other aviation organizations, such as the Aircraft Owners and Pilots Association and the Experimental Aircraft Association, can produce positive outcomes.

Additionally, The FAA should use it certification powers under Part 139 of the Federal Aviation Regulations (14 C.F.R. Part 139; FAA, 2016a) to require airports that conduct passenger-carrying operations to install technologic advances in order to promote a safer NAS. The FAA (2016a), through appropriate rulemaking, can require certain airports to be properly certificated and mandate that they meet established and stringent safety requirements (FAA, 2016a). When the FAA approves these requirements, the airports only legally operate commercial aircraft operations when they are in compliance.

Information resulting from this study will permit the FAA and its public administrators to increase as necessary the applicable standards under Part 139, thereby ensuring enhanced safety within the NAS. With an improved runway safety program, the number, types, and severity of runway incursions should decrease and the overall safety of the nation’s airports should increase, thereby making air transportation safer for the flying public. A worldwide reduction in runway incursions is critical in light of the forecasted growth in flight operations during the next several decades (FAA, 2015).

The FAA, foreign governments, and other aviation safety stakeholders should use the findings developed from this research study in improving their aviation safety programs designed to reduce runway incursions. By improving their runway safety programs, the overall safety of the air travel system throughout the world will improve, thus creating positive social change by enhancing human and social conditions relating to air travel. The findings from this study will be provided to the Runway Safety Team so they can use it to help improve the RSP and also provide critical safety information to pilots and the many others involved in the aviation industry.

Limitations of the Study

There are several limitations associated with this study. This study focused on whether the FAA 2009–2011 RSP has effectively reduced runway incursions at the five busiest U.S. airports. Limiting this study to the five busiest U.S. airports, decreases its applicability to general aviation airports where runway incursions are likely to occur. Generally, at the five busiest airports professional pilots are conducting large commercial aircraft operations carrying passengers and cargo. The type of flight operations, the pilots' proficiency levels, as well as the level of experience of air traffic controllers vary significantly from smaller general aviation airports. As such, the reasons for runway incursions at these smaller airports may be substantially different from those occurring at the nation's five busiest airports. When seeking to reduce runway incursions throughout the U.S., understanding the factors affecting runway incursions at these general aviation airports is critical.

An additional limitation is that this study only relied upon three dependent variables, including type, severity and phase of flight of the runway incursion. There are a number of other factors that could also influence runway incursions, such as pilot experience, weather conditions, airport complexity, as well as aircraft type (Rogerson & Lambert, 2012). Each of these factors could have an influence on whether a runway incursion is more or less likely to occur at a particular airport. This study was narrowly focused and its results are most applicable to larger airports conducting commercial operations. A more robust study which analyzes a greater number of variables would be helpful in providing a more detailed image of runway incursions throughout the entire NAS.

Finally, this study was quantitative in nature and did not consider other qualitative factors that could provide a more detailed picture of runway incursions throughout the NAS. Since runway incursions occur as a result of many factors (Rogerson & Lambert, 2012), truly understanding the reasons why runway incursions result from both the pilot and air traffic controller's viewpoint would be very helpful to the FAA when designing a more effective RSP. In future research studies involving runway incursions, the limitations inherent in this study could be overcome, thereby further enhancing the overall effectiveness of the RSP throughout the nation.

Recommendations for Further Study

Based upon the findings from this research study, several recommendations for further study naturally emerge. Finding ways to improve aviation safety is a goal shared by all aviation stakeholders. Further studies can help in determining what works best when reducing runway incursions. These researchers can explore runway incursions beyond the five busiest airports in the nation and consider this important aviation safety issue at all airports in the United States and potentially throughout the world.

One of the pending issues that remains unanswered and merits more study involves reasons why highly qualified professional pilots are still involved in a significant number of runway incursions resulting from pilot deviations. Increasing the understanding in this area is important when seeking the best ways to help pilots avoid runway incursions at the nation's five busiest airports in the nation and worldwide. Future researchers should conduct qualitative studies and incorporate surveys, focus groups, and other methods designed to explore reasons why highly qualified pilots are still having challenges with runway incursions. Findings from this study would assist in increasing knowledge regarding why pilot deviations are a growing cause of runway incursions at the five busiest U.S. airports. Also important for further study is a deeper understanding of the factors that encouraged a reduction in the number of operational errors by air traffic controllers. A qualitative study, including surveys and focus groups, involving air traffic controllers would be helpful in developing useful information that answers this important question.

Additionally, expanding this research study to include a larger number of airports across the nation would provide additional findings that incorporate not only professional pilots in its analysis, but also less skilled general aviation pilots. This would further broaden the focus of the findings from this research study and provide additional guidance and information to assist the FAA, foreign governments, and aviation safety stakeholders in more effectively reducing runway incursions and enhancing aviation safety.

The implementation of NextGen and its resulting influence on runway incursions and aviation safety is also a significant factor that needs to be explored. In many respects, NextGen will make aviation operations less complex for commercial operations and more complex for general aviation enthusiasts who must learn to operate in this new environment (FAA, 2016b). As part of NextGen, the FAA and aviation stakeholders are encouraged to work together as part of the NextGen Advisory Committee to "identify high-benefit, high-readiness NextGen capabilities for implementation in the near term" (FAA, 2016b, p. 3). This future study would be helpful to develop findings that could assist in reducing runway incursions and improving aviation safety within the NAS.

Finally, the increasing integration of Unmanned Aircraft Systems (UAS), commonly referred to as *drones*, into the NAS is also a significant concern that could have a substantial effect on aviation safety. The FAA (2016c) expects UAS within the NAS to increase from 1.9 million in 2016 to approximately 4.3 million by 2020.

Meanwhile, commercial sales of UAS are forecasted to increase from 600,000 in 2016 to approximately 2.7 million by 2020 (FAA, 2016c, p. 1). Future researchers should focus on the potential influence of this rapid UAS integration into the NAS and its potential impact on aviation safety as well as its potential to negatively influence runway incursions. As UAS are likely to substantially increase within the NAS during the next several decades, research considering their influence on aviation safety as well as its implications on the efficient operation of the NAS is of critical importance.

In conclusion, several areas exist where additional research would be helpful in developing information that could improve aviation safety and have a positive effect on reducing runway incursions throughout the nation. With additional knowledge, the FAA, foreign governments, and all aviation safety stakeholders can stay focused on improving aviation safety throughout the NAS and the world.

Chapter Summary and Conclusion

This chapter provided an interpretation of the results from the research study. It further addressed implications for social change and provided recommendations for future action and studies. The chapter served to clarify the results of this study within the context of aviation safety.

Runway incursions have been a serious problem jeopardizing aviation safety worldwide for decades. The FAA has worked diligently to decrease the number and severity of runway incursions since the implementation of the RSP. The research problem presented in this study was whether the FAA 2009–2011 RSP effectively reduced runway incursions at the nation's five busiest airports. I sought to determine whether the RSP was effective in reducing runway incursions by examining their types, severity, and phases of flight using data from 3 years before and 3 years after the FAA 2009–2011 RSP. An analysis of the data produced established that although the RSP has made some progress, it has not effectively reduced runway incursions at the nation's five busiest airports. Limited progress has been made to decrease the severity of runway incursions as well as positively influencing the phase of flight that incursions most often occur, but increased emphasis needs to be placed on decreasing pilot deviations within the NAS.

The FAA, foreign governments, and aviation stakeholders across the world should use the findings from this study to effectively modify future runway safety programs. By utilizing these findings, the number of runway incursions will decrease, thereby improving aviation safety for the flying public and assisting in the continued development of the aviation industry around the world. Through safer aviation, an increasing number of the world's people will be able to enjoy aviation-related jobs and the aviation industry will continue its significant development for many years into the future. This results in positive social change for the many people throughout the world who rely, or will rely, on aviation for the improvement of their lives.

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