

Abstract

This research presents the process for a systematic literature review examining factors that contribute to runway incursions (RIs). A systematic literature review uses other research results as data for systematic analysis. Runway safety is a top priority. In the US, RIs have been increasing and typically three RIs occur every day. This paper identified 134 articles using 22 databases. Filtering criteria and analysis identified six contributing categories: human factors, airport geometry, technical factors, airport characteristics, environmental factors, and organizational factors. Recommendations for reduction of RIs and suggestions for further studies are presented based on these factors.

Introduction to Systematic Literature Review

What is a systematic literature review?

A systematic literature review is an analysis of previous research using a systematic and explicit method to identify, select, and critically appraise relevant studies and to collect and analyze data from them.

Systematic Literature Review in Other Disciplines

Systematic literature reviews are used in many other fields as shown in Figure 2. Systematic literature reviews are rarely used in aviation, and have not been used to address runway safety or RIs. Systematic literature reviews in aviation are related to medical and health-related aviation topics.

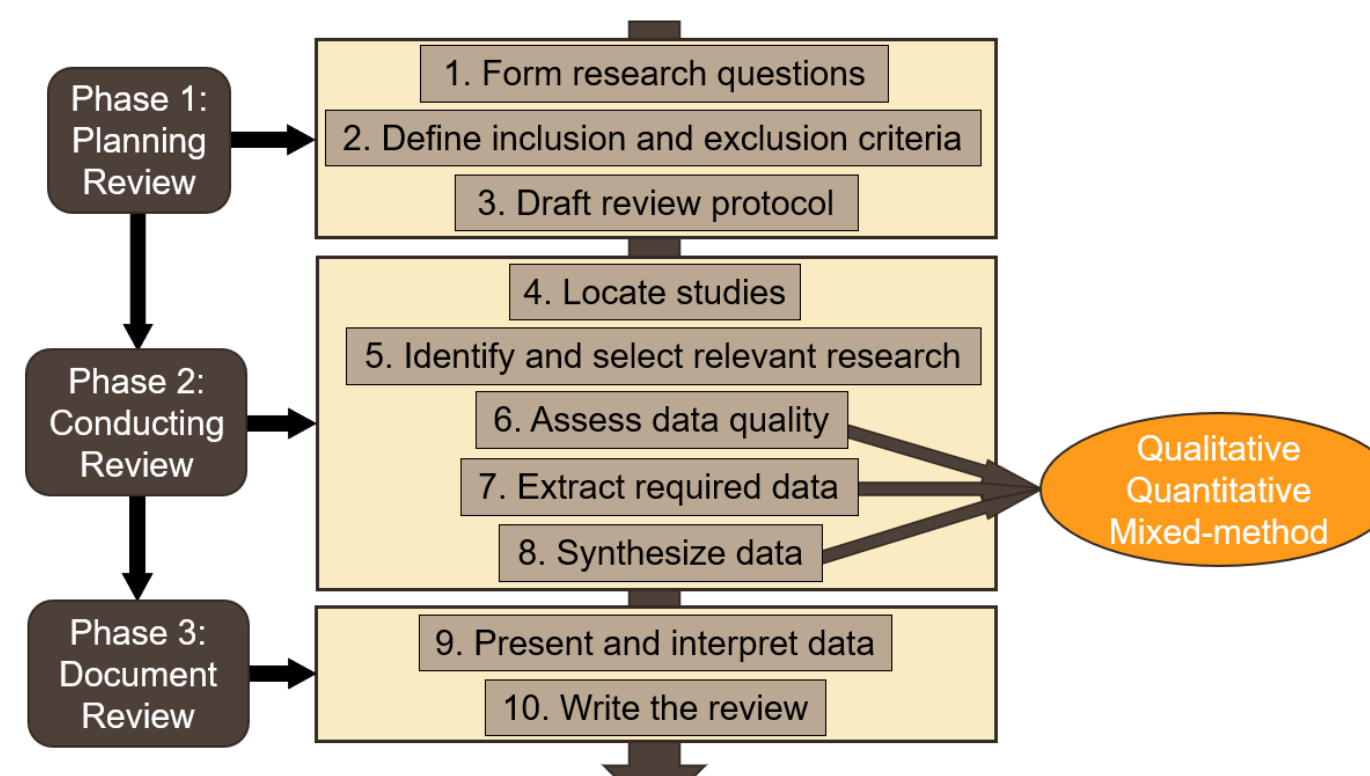


Figure 1. Steps for Conducting a Systematic Literature Review

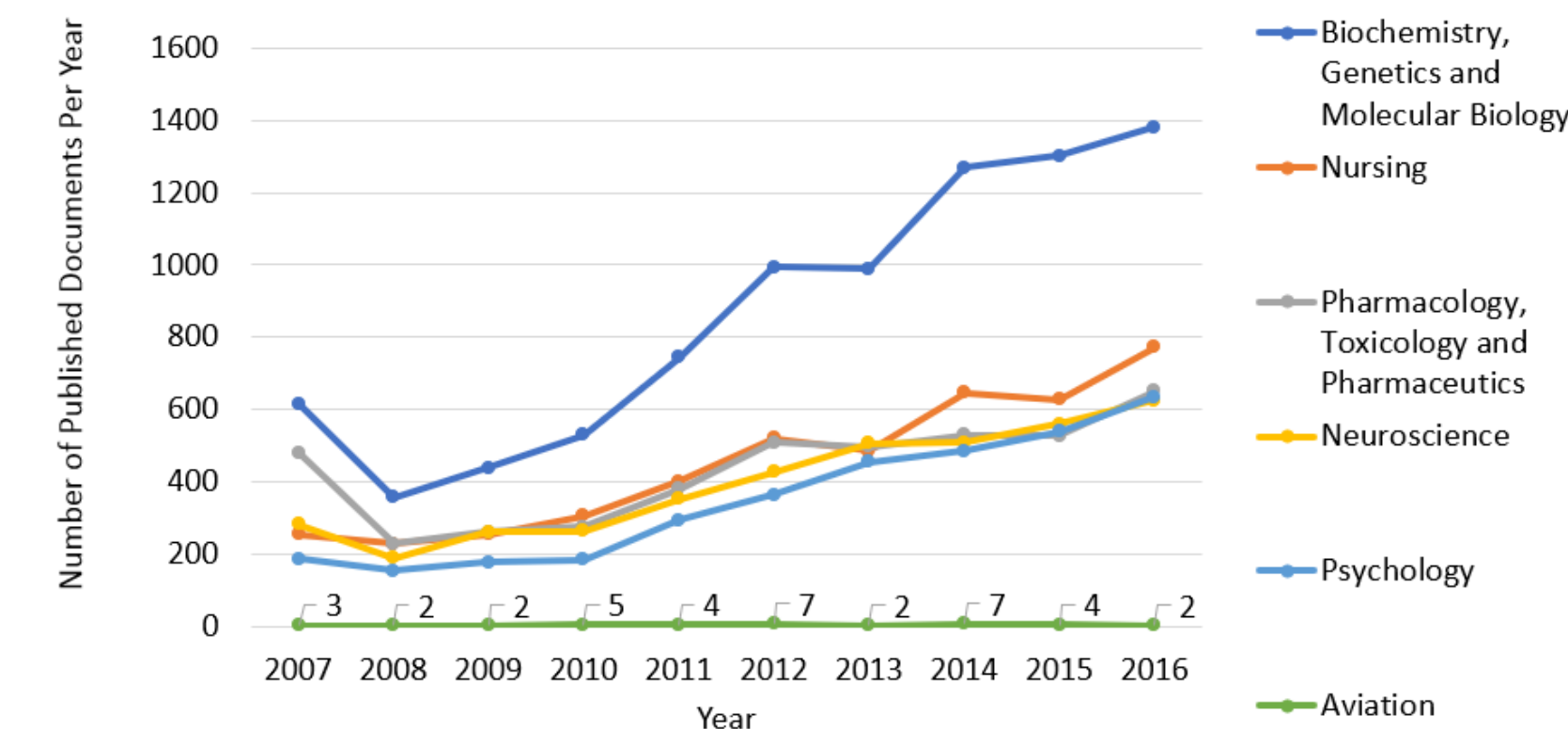


Figure 2. Number of systematic literature reviews by subject and year, 2007-2016, data source: Scopus.

Background on Runway Incursion

What is a 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 take-off of aircraft.

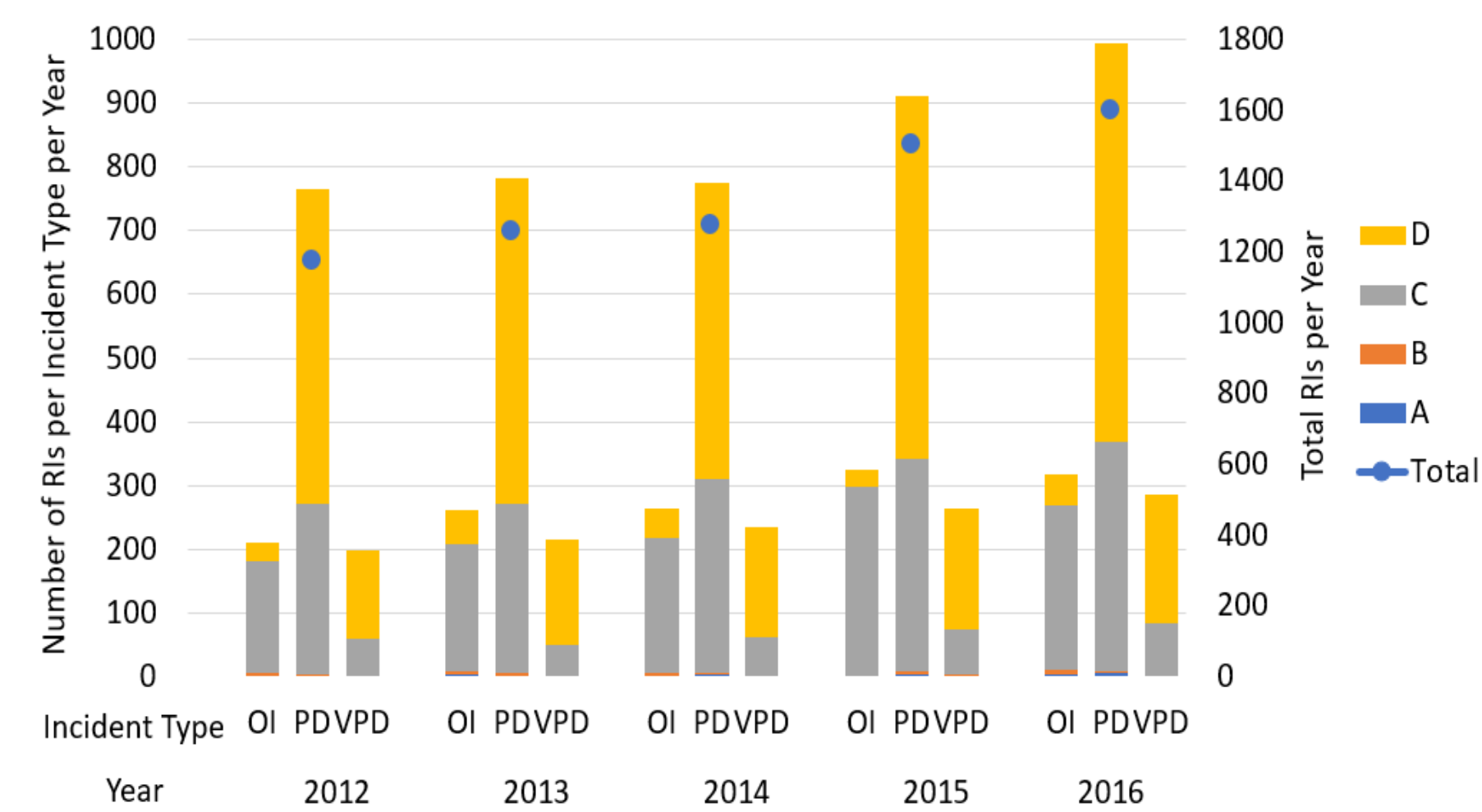


Figure 3. U.S. RI totals by cause for fiscal years 2012-2016.

Runway Incursion Incident Types

Operational Incident (OI)	A RI due to the action of a pilot that violates any Federal Aviation Regulation. A RI due to the action of an air traffic controller.
Pilot Deviation (PD)	This includes actions that result in a situation in which a separation is less than the required minimum. The separation may be between two or more aircrafts, or between aircraft and vehicles. This would also include clearing an aircraft to take off or land on a closed runway.
Vehicle/ Pedestrian Deviation (VPD)	A RI due to a pedestrian or vehicle entering any portion of the airport movement area include runways and taxiways, without authorization from air traffic control.

Runway Incursion Severity Categories

Increasing Severity				
Category D	Category C	Category B	Category A	Accident
An incident that meets the definition of RI, such as the incorrect presence of a vehicle, person, or aircraft on the runway or protected area, although there are no immediate safety consequences.	An incident characterized in which there is ample time and/or distance to avoid a collision.	An incident in which separation decreases and there is a significant potential for the collision; this may require a time critical corrective response or evasive response to avoid a collision.	A serious incident in which a collision was narrowly avoided.	An incursion that resulted in a collision.

Research Motivation and Scope

According to the FAA, 32 category A RIs and 43 category B RIs occurred in the five years between 2012 and 2016. During this time period, there were more than 6,000 RIs classified as category C or category D. This is consistent with research conducted by Heinrich, who found that for every accident that causes a major injury, there are 29 incidents that cause minor injuries and 300 incidents that cause no injuries. Identifying and reducing RIs of all categories will help reduce the likelihood of severe RIs that may cause injury or death.

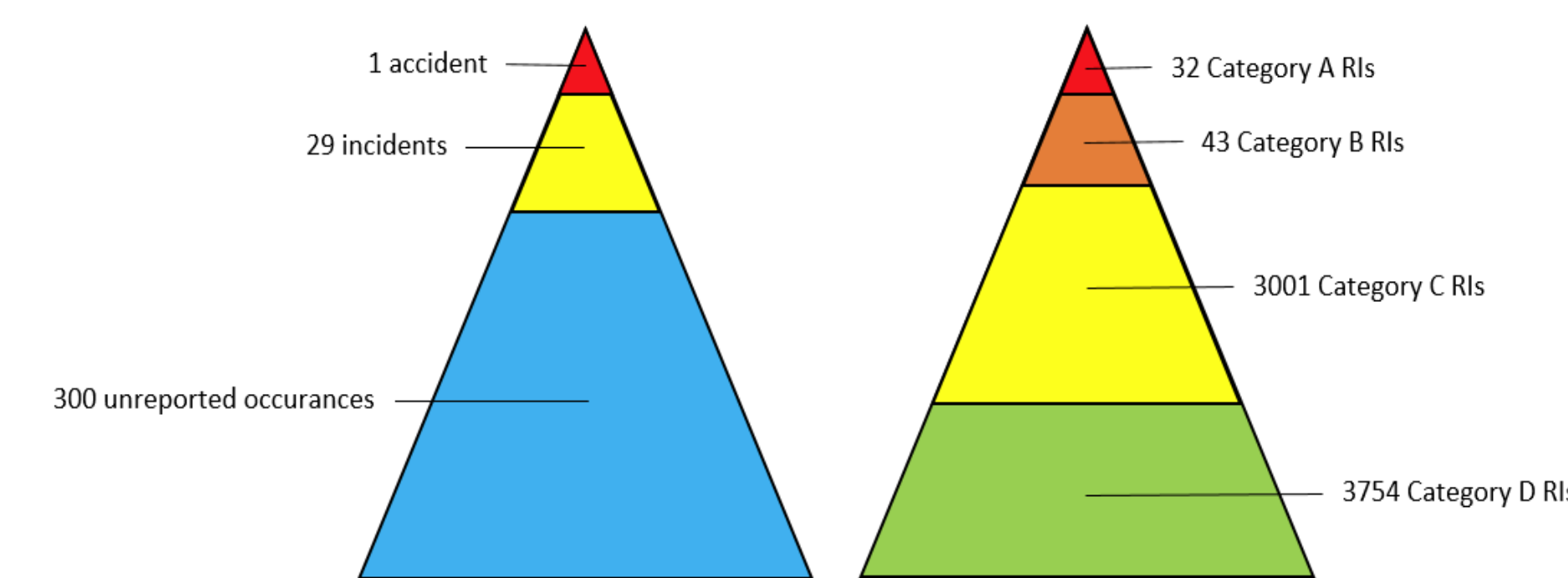


Figure 5. Heinrich pyramid, left, and its application to RIs severity, right.

Critical Role of RIs in Aviation Safety

RIs are a critical concern for the safety of the air transportation system. In the worst case, a RI can result in a collision and loss of life.

Steady Rise of RIs in the U.S.

According to the statistics, the number of flights in the United States has decreased slightly since 2012, however, the number of RIs has continued to increase during the same time period.

Methodology

The methodology used in this study is a systematic literature review based on guidelines outlined in the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement". These guidelines were used to conduct a systematic literature review of correlating factors contributing to a higher incidence of RIs.

Inclusion Criteria and Search Strategy

Peer review journal articles and conference papers published since 2008 in English that provide quantitative and/or qualitative assessment with any of the following words as key words or in the title or abstract: statistics of RIs, severity of RIs, type of RIs, factors that contribute to RIs.

Data Sources

Twenty-two databases were used including Engineering Village, ProQuest Technology Collection, Transportation Research Information Database (TRID), and 19 other databases.



Exclusion Criteria

Articles were excluded if they evaluated specific methods and technologies to prevent or reduce RIs; focused on validation of the new technologies about RIs; focused on air traffic safety; or were not peer reviewed (e.g., books, newspaper articles, presentations, and government reports).

Systematic Literature Review Process and Selected Articles

This paper presents the results from these 22 research papers which are presented in the tables below, with the author, year of publication, title, and analysis method used. In quantitative studies, a variety of statistical and mixed-methods are used. Quantitative methods include t-tests, multiple regression models, Pearson Chi-Square tests, and multinomial logit models, all of which are used extensively in many aviation-related research studies. Qualitative methods which are incorporated into mixed-method research studies include the Likert scale, analytic hierarchy process, preliminary hazard analysis, and fault tree analysis. The qualitative methods used in aviation research are more generalized, and include narrative research, surveys, and semi-structured interviews.

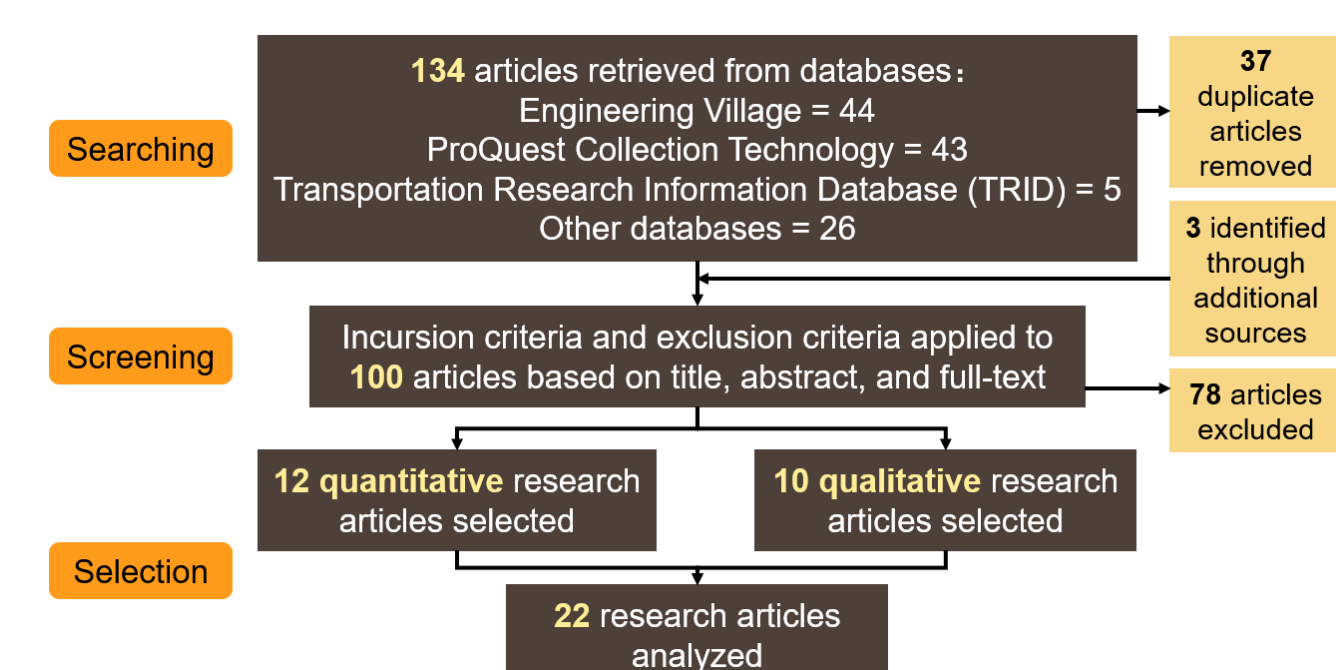


Figure 5. Systematic literature review process.

Author (Year)	Title
Chang & Wong (2012)	Human risk factors associated with runway incursions
De Reuck, Donald, & Siemers (2014)	Factors associated with safety events in air traffic control
Goodheart (2014)	Identification of causal paths and prediction of runway incursion risk by means of Bayesian Belief Networks
Johnson, Zhao, Faulkner, & Young (2016)	Statistical models of runway incursions based on runway intersections and taxiways
Joslin, Goodheart, & Tuccio (2011)	A mixed method approach to runway incursion rating
Ju (2011)	Reason analysis of runway incursions based on Grey Theory
Kim & Yang (2012)	Evaluation of the risk frequency for hazards of runway incursion in Korea
Mathew, Major, Hubbard, & Bullock (2016)	Statistical modelling of runway incursions
Mrazova (2014)	Runway Incursions - clear and constant danger
Stroeve, Blom, & Bakker (2013)	Contrasting safety assessments of a runway incursion scenario: event sequence analysis versus multi-agent dynamic risk modelling
Wilke, Majumdar, & Ochieng (2015a)	Modelling runway incursion severity
Wilke, Majumdar, & Ochieng (2015b)	The impact of airport characteristics on airport surface accidents and incidents

Table 1. Articles with Quantitative Research

Author (Year)	Title
Asare & Ford (2008)	Reducing runway incursions - A simple, yet effective next step
Cardosi, Chase, & Eon (2010)	Runway safety
Leon (2009)	Combating runway incursions
Oetzell (2008)	Avoiding runway incursions
Redzepovic (2009)	Prevention of runway incursions at joint use aerodromes
Rogerson & Lambert (2012)	Prioritizing risks via several expert perspectives with application to runway safety
Rogerson, Lambert, & Johns (2013)	Runway safety program evaluation with uncertainties of benefits and costs
Stroeve, Som, Van Doorn, & Bakker (2016)	Strengthening air traffic safety management by moving from outcome-based towards risk-based evaluation of runway incursions
Wilke, Majumdar, & Ochieng (2012)	Holistic approach to airport surface safety
Wilke, Majumdar, & Ochieng (2013)	Airport surface operations: A holistic framework for operations modeling and risk management

Table 2. Articles with Quantitative Research

Results of Quantitative and Qualitative Research

Six main categories of contributing factors were identified based on the 12 quantitative and 10 qualitative research papers:

- human factors (the most often cited),
- airport geometry,
- technical factors,
- airport characteristics,
- environmental factors, and
- organizational factors.

Human Factors is most often cited as a contributing factor. Human factors can affect pilots, air traffic controllers, pedestrians, and ground vehicle drivers.

Airport Geometry is the second most often identified contributor to RIs. As the complexity of airport geometry increases, RIs increase. Intersecting runways, intersections of runways and taxiways, the number of conflict points, complex intersections or airport layouts all increase airfield complexity.

Author's Last Name (Year)	Human Factors	Airport Geometry	Technical Factors	Airport Characteristics	Environmental Factors	Organizational Factors	Number of Factors Discussed in Each Article
Chang & Wong (2012)	✓		✓	✓			3
De Reuck et al. (2014)	✓		✓			✓	3
Goodheart (2013)	✓				✓	✓	4
Johnson et al. (2016)		✓					1
Joslin et al. (2011)	✓						1
Kim & Yang (2012)	✓						1
Mathew et al. (2016)					✓		2
Mrazova (2014)	✓	✓					3
Stroeve et al. (2013)	✓		✓				1
Wilke et al. (2015a)		✓					1
Wilke et al. (2015b)		✓					1
Total number of articles identifying each factor	7	5	3	3	2	2	

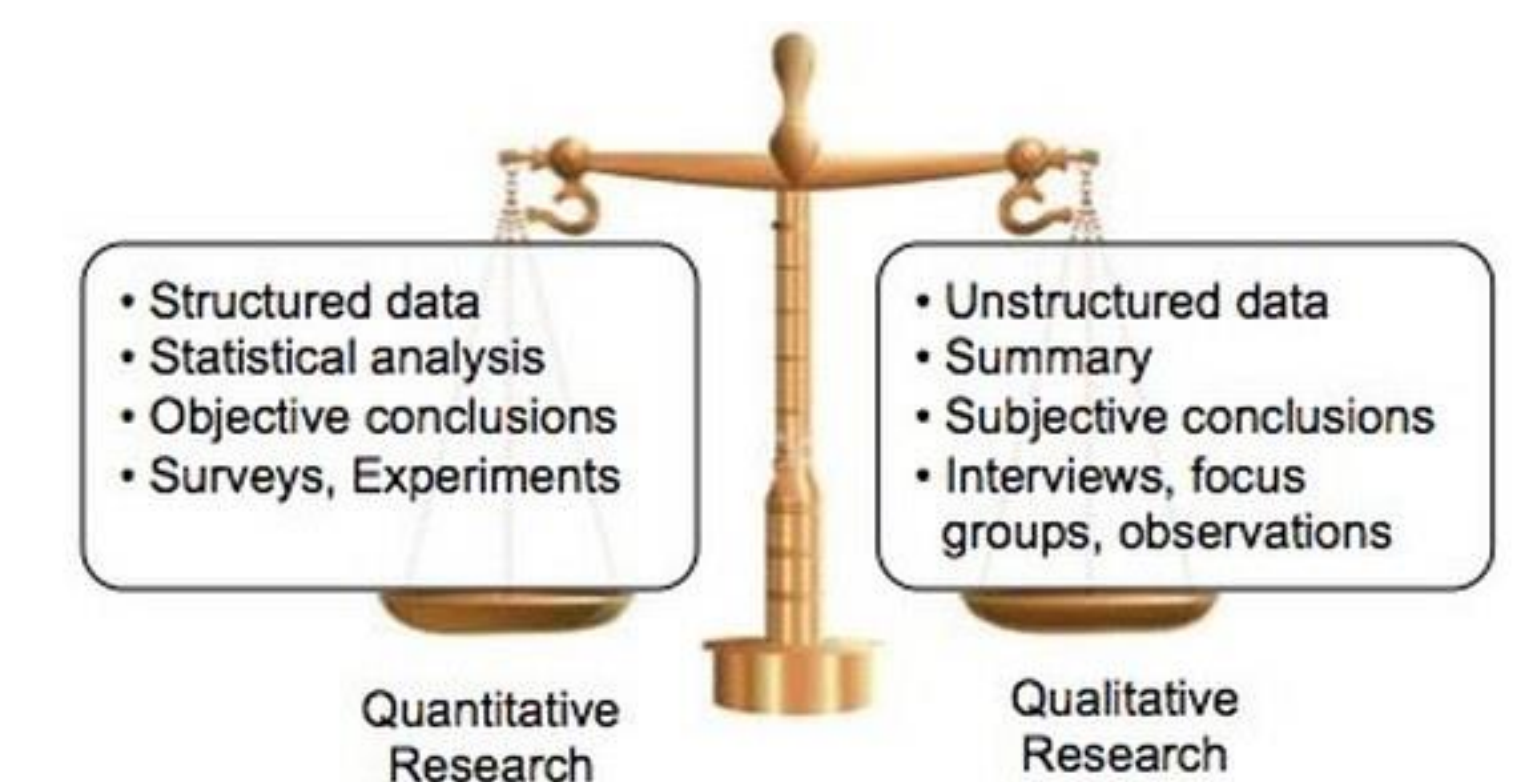
Table 3. Factors Contributing to RI Identified in Quantitative Analysis

Author's Last Name (Year)	Human Factors	Airport Geometry	Technical Factors	Airport Characteristics	Environmental Factors	Organizational Factors	Number of Factors Discussed in Each Article
Cardosi et al. (2010)	✓	✓	✓			✓	4
Leon (2009)	✓	✓					2
Redzepovic (2009)	✓		✓	✓		✓	4
Rogerson & Lambert (2012)		✓		✓	✓	✓	4
Rogerson et al. (2013)		✓		✓	✓	✓	4
Stroeve et al. (2016)	✓						1
Wilke et al. (2012)	✓	✓	✓	✓	✓		5
Wilke et al. (2013)	✓	✓	✓	✓	✓		5
Total number of articles identifying each factor	6	6	4	5	4	4	

Table 4. Factors Contributing to RI Identified in Qualitative Analysis

Comparison of Quantitative Research and Qualitative Research

Qualitative research typically identifies more contributing factors for RIs than quantitative research. The majority (6 of 8) of qualitative research studies identified at least four contributing factors for RIs, whereas only one (of 12) quantitative research study identified four contributing factors. Quantitative research papers often focus on only one or two specific contributing factors. This may reflect challenges capturing some categories of contributing factors with statistical methods. All quantitative research studies were published after 2011, whereas most qualitative research studies were conducted before 2013.



Recommendations and Discussion

Recommendations for Runway Incursions

To address **human factors** is to conduct initial and continuous training for pilots, air traffic controllers and ground operators to mitigated all causes of RI, including PD, IO and VPD incursions. Human factors training may focus on both technical and non-technical skills.

Recommendations also address **airport facilities**, including airport geometry, airport characteristics, and airport technical factors. In some cases, RI can be addressed by reducing airfield complexity, including the number of intersections and conflict points.



Further Research

The systematic literature review methodology may be used to investigate other topics in aviation, as well as an expanded investigation of RIs. Expansion of the study to include agency reports could encompass the findings of the FAA Runway Safety Reports between 2008 and 2014, the FAA National Runway Safety Plan for 2015 to 2017, and The European Action Plan for the Prevention of Runway Incursions published by the Eurocontrol.

Conclusion

A reduction of RIs is a top priority for FAA and an important activity to ensure aviation safety. This study demonstrates the process for a systematic literature review an investigation of RIs using quantitative, mixed-method and qualitative analysis published in peer-reviewed journal and conference papers. Six contributing factors to RIs were identified: human factors, airport geometry, technical factors, airport characteristics, environmental factors, and organizational factors. This research demonstrates the value of this systematic approach to synthesize research findings from multiple studies, and advance research, increase safety, and optimize efficiency in the aviation sector.