Demographic Factors for Prioritization of Airport Safety Audits

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AUTHOR

The thesis has been read and approved by the examining committee:

Dr. James H. Lambert

Advisor

Dr. William T. Scherer

Dr. Laura Barnes

Accepted for the School of Engineering and Applied Science:

Dean, School of Engineering and Applied Science

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Abstract

With the large-scale complex and emergent nature of airport systems, comprehensive and adaptive risk management is necessary to address safety in a planning horizon of multiple years. Factor based prioritization has been used to identify and rank facilities with higher potential for incidents, allowing stakeholders and officials to effectively allocate resources for maximum effectiveness and learning. Past analytical approaches have focused the physical characteristics of facilities, as well as the rare-event frequencies of historical incident types and their precursors. The US Federal Aviation Administration cites human error as a significant future threat to aviation safety. Nevertheless, little work has addressed the identification and measurement of human and cultural safety factors at the airport scale. This thesis explores how to include demographic factors of the vicinities of the facilities in order to begin to account for potential human, cultural, and organizational issues in the prioritization of regulatory safety audits. The approach will define several new factors, assess the factors from available databases, test their uniqueness and relationships to other factors, and integrate them to existing frameworks of prioritizing safety audits. The methods to be adapted and integrated for this purpose are exploratory data analysis, multivariate statistical inference, expert elicitation and model building, hierarchical data models, multicriteria analysis, and uncertainty analysis. The results will be useful to regulators and airport managers in their oversight of a range of current and future technologies, diverse geographic locations, organizations, and time and spatial scales. In addition, the results will be useful in other technology domains seeking to use available and indirect evidence of human, organizational, and cultural issues in systemic risk management of large-scale complex systems.

Chapter 1. Introduction

1.1 Chapter overview

This chapter provides an introduction to the use of demographic factors in a priority setting framework for the allocation of airport safety audits. Section 1.2 will provide a motivation for the current work. Section 1.3 will identify the problem statement and scope, specifically the need for an approach to quantify the human aspects of aviation safety. Section 1.4 highlights the goals and objectives of this thesis.

1.2 Motivation

Transportation and other complex systems involve risk management to improve system safety. Aviation, in particular, represents a high risk system due to the many characteristics which distinguish it from simpler modes of transportation (Janic, 2000). Current and future increases in aviation demand, traffic and technology are likely to pose a continued threat to the safety and reliability of these systems. Risk and safety programs are an effective way of managing this risk and helping to improve safety and reliability.

Runway safety, one of highest priorities of the Federal Aviation Administration (FAA), can be monitored and improved through the implementation of a safety program. Runway safety can be quantitatively assessed through instances of runway incursions. The FAA defines a runway incursion as any unauthorized intrusion onto a runway (FAA, 2009). Although incursions are not always responsible for physical damage, they can represent the potential for dangerous situations and in some cases severe accidents (FAA, 2009). By tracking instances of runway incursions, the FAA has the ability to effectively monitor the nearly 500 towered airports in the United States. The monitoring of runway incursions also assists the FAA in choosing airport locations for safety meetings and intervention. These meetings serve as the primary pillar of the safety program of the FAA. Meetings with the airport stakeholders and officials can lead to vastly improved safety conditions.

Rogerson and Lambert (2012) identify many factors that can be used to highlight airports with a higher risk of runway incursion. They describe the importance of identifying a full understanding of the runway system, and the many causes of runway incursions. Rogerson and Lambert (2012) identify many physical and geographic factors, as well as historical operations data, that are likely to influence instances of runway incursions. Physical features, including complex runway geometry or unusual runway configurations, as well other distinguishing characteristics, such as the presence of a flight school, are of importance. Additional information, such as past instances of runway incursion and daily flight operations, can also be used to identify airports with greater risk for incursions. Airports with historical safety issues might be likely to experience higher instances of runway incursions.

Currently, these factors, and the associated safety concerns, are under discussion by the FAA Office of Runway Safety. Much of the discussion centers on mitigation of threats due to these factors.

While Rogerson and Lambert (2012) present several important and significant factors and provides preliminary methods for identifying high risk airports, there is an additional category of factors that can contribute to an increased risk of runway incursion. In addition to the factors previously described, it is important that *human and cultural factors* also be considered for the prioritization of airports for safety audits.

1.3 Problem statement and scope

While human and cultural factors have typically had a role in analyzing the safety and reliability of engineering systems, the recent surge in complexity and scope of systems, including nuclear and commercial aviation, has led to renewed and increased interest. Catastrophic events have served as catalysts to promote investment in the understanding of human error. Despite this increased focus, there is still concern as to whether the present pace of human factors research is adequate to cope with the increased development of complex systems (Rasmussen, 2012).

Much of the effort focused on understanding human and cultural factors is confronted by challenges stemming from an inherent uncertainty. While additional resources will continue to be allocated for research and development in understanding the role of human and cultural factors in engineering, many of these challenges will persist. They include, but are not limited to difficulties in identifying those aspects of human behavior which contribute to risk and system failure, determining and quantifying directly relevant human and cultural factors, and developing models to incorporate the factors.

Olguín *et al*. (2009) point out the subjectivity that is often found in attempts to measure and evaluate human behavior. This subjectivity can represent a threat to both the accuracy and quantity of relevant data. Without uniform methods for collection and evaluation, discrepancies are likely to occur, especially in large scale applications.

Lund and Aarø (2004) describe that few models have incorporated aspects of our cultural, organizational and physical surroundings. It is often hard to quantitatively examine the effect of these factors. There is some doubt as to whether human factors and culture can be measured (Lund and Aarø, 2004). Qualitative assessment is often the primary tool used for human error analysis and while useful to some extent, can only account for certain aspects. The introduction of more quantitative techniques will assist in developing a further understanding.

Methods to identify, quantify and incorporate human and cultural factors could be used for improvements in runway safety. Such methods could be used for adaptive risk management in order to account for evolving aspects of runway safety. Such methods could also have application to other complex systems by addressing human and cultural factors that represent fundamental threats to system safety.

1.4 Goals and objectives

This section will highlight the goals and objectives of this thesis. The primary goal is to investigate the role of human and cultural factors in airport runway safety and the subsequent effects on risk management. As previously mentioned, it is necessary for the inclusion of human and cultural factors to support comprehensive risk management of runway systems.

Additional objectives are described as follows. The first objective is to conduct a preliminary investigation to identify the importance of human and cultural factors in accident prevention and risk management in complex systems. The second objective is to identify those human and cultural factors which are likely to have a significant impact on airport runway safety. The third objective will be to introduce a method for uniform quantification of the identified factors. The fourth objective will focus on an exploratory analysis to gain a better understanding of the relationship between human and cultural factors and runway incursions. The fifth objective will be to incorporate the newly quantified factors into prioritization frameworks for safety audits. The sixth objective will be to analyze the effect of the factors on risk management through an in depth review of changes to the ranking of highly prioritized airports.

Chapter 2. Background

2.1 Chapter Overview

This chapter provides a background of the effects of human behavior on risk management and incident prevention. Section 2.2 will provide a review of work focused on the role of human and cultural factors in ensuring system safety and reliability. A review of the literature will help to identify previous attempts to model the effect of these factors, as well as opportunities for improvements in the models. Additionally, this section will provide background and justification for the inclusion of human and cultural factors in understanding and improving runway safety. Literature from the FAA, as well as other aviation focused organizations and studies will serve as the basis for this analysis. Section 2.3 will discuss existing factors included in runway safety analysis and will provide a justification for the inclusion of an additional class of human and cultural factors. A review of previous efforts will help to identify both necessary improvements as well as techniques that can be used for seamless integration of the new class of human and cultural factors.

2.2 Literature review

This section will discuss literature relevant to the role of human and cultural factors in risk management and system safety. Additionally, this section will identify important relationships between these factors and runway safety. Significant work has been devoted to the study of human behavior and its effect on risk management and system safety. There is consensus that human and cultural based factors ought to be included in risk management methods. Studies supported by the FAA and other aviation based organizations will help to identify the need for the inclusion of human and cultural factors in safety analysis, specifically as it relates to runway safety and incursion reduction. A thorough understanding of the role of human and cultural factors in risk management can be combined with aviation specific human based challenges to develop the class of human and cultural factors for runway safety initiatives.

2.2.1 Human factors: risk management and system safety

Weick and Sutcliffe. (1999) describe that organizational, managerial and human factors, rather than purely technical failures are prime causes of accidents in high reliability industries. Weick and Sutcliffe (1999) further describe that a variety of complex systems, including aviation, are vulnerable to failures resulting from these specific factors. The role of non-technical factors in risk management and system safety is described by Pidgeon and O'Leary (2000). They describe the way in which social and organizational preconditions leave systems vulnerable. The inclusion of human and cultural factors in risk management and systems safety becomes essential with increasing levels of system complexity. Murphy and Paté-Cornell (1996) describe the way in which failures in complex systems frequently point to organizational and human problems as their root causes. They argue that in order to implement effective risk management and improve system safety, system management must understand and influence these human and organizational factors.

While there is strong consensus for the inclusion of human factors in risk management and system safety, there is less work devoted to the development of models to incorporate these factors. Modeling in large-scale complex systems is often reliant on observable factors that contribute to volatility within the system (Thekdi and Lambert, 2012). Models must be able to accurately utilize the component parts of any complex system (Lambert *et al.*, 2006). Because the underlying aspects of human behavior can be uncertain and often subjective, component identification can be a difficult task. In turn, model development is restricted. There is widespread agreement that this significant lack of modeling is preventing an accurate understanding of some significant effects of human factors.

Murphy and Paté-Cornell (1996) describe that while classical risk analysis techniques can accurately model the physical systems, they are not able to account for the human and organizational factors. Grabowski *et al.* (2009) describe the difficulties in identifying and modeling human and organizational factors in large complex systems. These modeling limitations must be addressed to reduce the challenges that exist in accurately identifying the role of human factors in risk management and system safety.

2.2.2 Human factors: aviation safety

Due to the large-scale complex nature of aviation systems, the role of human and cultural factors is significant. An understanding of these factors in the context of the aviation can help to identify a potential relationship to runway safety, specifically runway incursions.

Human and cultural factors have been constantly addressed throughout the history of aviation and a thorough understanding of these factors has led to significant improvements in numerous aspects of aviation. However, as system complexity increases, new approaches and methods must be introduced. If the FAA and the aviation industry are to achieve their goal of significantly reducing the aviation accident rate over the next ten years, the primary causes of aviation accident (i.e., human factors) must be addressed (Wiegmann and Shappell, 2001). In fact, some estimates suggest that 60% to 80% of aviation incidents can be attributed, at least in part, to some sort of human error and it is likely this number will continue to grow (Wiegmann and Shappell, 2001). Nagel (1988) describes that with increasing reliability in aircraft technology, human error has played a progressively more important role in accident causation. While an initial set of remedies have been implemented, what remains are several issues relating to human error (Shappell and Wiegmann, 2009).

Accounting for human factors must involve a thorough analysis focused on primary root causes. Common practice can neglect the investigation of the conceptual and preliminary phases (Kontogiannis and Malakis, 2009). In fact, most reviews of aviation incidents fail to venture at all into the analytical phase of explaining root cause (van der Schaaf, 1995).

Shappell *et al.* (2007) describe a difficulty that arises when attempting to apply a methodology that includes human and cultural factors. Specifically, they note the investigation of human factors is often a review of the narrative, and ways of quantifying the factors remain unidentified. Wiegmann and Shappell (2001) emphasize that while effective means exist for identifying physical factors, variables and terms associated with human factors are ill-defined and data is poorly organized. Additionally, it is noted that analytical techniques for these factors are less refined and sophisticated than others. Inclusion of human factors within a quantitative framework will be invaluable in efforts to improve aviation safety (Wiegmann and Shappell, 2001).

2.3 Runway safety factors and airport prioritization

Rogerson and Lambert (2012) describe a method for prioritization of airports based on factors relevant to runway safety. These efforts focused on identification of factors that could aid a prioritization effort to help bring attention to high risk airports that would most benefit from safety evaluation and meetings. In addition to identification of factors, Rogerson and Lambert (2012) develop a framework in which these factors could be quantitatively incorporated. This work represents one of the first attempts to utilize a factor based approach for the risk management of runway systems. An overview of the past effort will help to highlight the necessary steps for inclusion of human and cultural factors.

2.3.1 Airport prioritization

The FAA is dedicated to ensuring runway safety at the airports across the nation. Runway Safety Action Teams (RSATs) are one of the primary tools of the FAA in addressing issues relating to runway safety. When RSAT meetings are conducted at airports, their objective is two-fold: to address existing safety concerns and to develop plans to address potential future issues. RSAT meetings utilize a multi-faceted approach which includes observation, data analysis, expert opinions and meetings with airport stakeholders. RSAT meetings are considered to be an important contributor to maintaining or improving runway safety. Highlights from a May 2012 RSAT meeting conducted at Dulles International Airport can be found in the appendix.

However, while the FAA understands both the importance of runway safety and the effectiveness of RSAT meetings, resource limitations require an evidence-based method for prioritizing airports to receive an RSAT. For example, during fiscal year 2012, in the FAA Great Lakes region, only four of the eighty airports were able to receive an RSAT meeting (FAA, Great Lakes). It is necessary that airports receiving the RSAT meetings represent those airports with the highest risk and highest potential for learning about the national airspace system as a whole.

2.3.2 Runway safety prioritization factors

In her initial work, through an approach utilizing Hierarchical Holographic Modeling (HHM), Rogerson and Lambert (2012) identify a variety of factors relevant to ensuring the safety of runway systems (Haimes *et al.*, 2002). These identified factors seek to represent the runway system in a holistic sense and are described in detail below.

The first factor seeks to represent the complexity of the runway geometry of an airport. The more complex the geometry of a runway, the greater the risk for runway incursion, as certain runway configurations can be difficult to understand and correctly navigate. The runway complexity can affect both air based crew and ground based grew. An aggregate runway geometry factor consists of a count of the following: closely aligned runways, crossing runways, multiple crossing runways, parallel runways, short taxi routes and bullseye formation.

The second factor focuses on the airport itself and the certain characteristics that can lead to a greater risk of incursion. This factor consists of a count of the following: need for 139 airport certification, presence of a flight school and status as a federal contract tower. The presence of these characteristics can contribute to several types of risk factors that can influence runway safety. For example, the presence of a flight school can contribute to an increase of student pilots on airport grounds. Student pilots often lack certain familiarity with procedures, regulations and guidelines and can be more likely to make mistakes which lead to runway incursion.

The final three factors deal with historical operations and can be useful in determining the general tendencies of an airport. The factors are as follows: number of runway incursions, runway incursion rate per 100,000 operations and total operations. Historical operations data can be very useful in identifying high risk airports. Increased yearly operations can lead to higher risk due to the increased potential for incidents. Busier airports with large operations must constantly address the risk of numerous airplanes, vehicles and personnel working on grounds. Past incursions can also be useful in identifying tendencies across airports. If unaddressed, the factors which contributed to previous incursions are likely to contribute to future incursions. The incursion rate can help to distinguish between airports where incursions are frequent and systematic and locations where they are rare events.

The previously described factors are summarized in Table 1.

Table 1. Existing factors for prioritization of runways to receive airport safety audits

Factor	*Description*
Runway Geometry	Sum of closely aligned runways, crossing runways, multiple crossing runways, parallel runways, short taxi routes, bullseye formation
Airport Features	Sum of need for 139 Airport certification, presence of a flight school, status as federal contract tower
Runway Incursions	Total number of runway incursions (per year)
Runway Incursions per 100,000 Operations	Runway incursion rate (per year)
Airport Operations	Total operations (per year)

Chapter Summary

This chapter investigated the role of human and cultural factors in modeling and evaluation of complex systems. A literature review described the current need for methods to quantitatively represent and incorporate human and cultural factors into risk management frameworks. Significant work focuses on the physical features of a system, however, growing complexity requires human and cultural factors also be addressed. Despite a clear and demonstrated need for inclusion of human and cultural factors in risk management models, few approaches have been identified.

A prioritization method developed by Rogerson and Lambert (2012) can be used for prioritization of airports to receive the assistance of an RSAT meeting. The factors presented by Rogerson and Lambert provide a method for prioritization based on physical features and historical operations data. These prioritization factors, while important and likely contributors to risk in runway systems, would benefit from the inclusion of a class of human and cultural factors. The next chapters will describe methods for the identification, quantification and incorporation of human and cultural factors.

Chapter 3. Human and cultural factors in runway safety

3.1 Chapter overview

This chapter will describe a selection of human and cultural factors for use in prioritizing airports for risk of runway incursion. A comprehensive approach was utilized to identify and incorporate relevant human and cultural factors. This multi-faceted approach was designed to evaluate all aspects of airport operations with the ultimate goal of isolating those human and cultural factors which are potentially significant to runway incursions. Section 3.2 will describe the onsite observation process that was utilized to gain a preliminary understanding of runway processes and the relevant human and cultural factors. Section 3.3 will outline the involvement of airport officials in a further examination of the runway system and human and cultural factors. Section 3.4 examines the use of English proficiency as a human and cultural factor. Section 3.5 examines the use of ground vehicle operations as a human and cultural factor. Section 3.6

provides narratives from the FAA incursion database highlighting the human and cultural factors.

3.2 Airport observation

Preliminary work involved observation of basic characteristics and operational tendencies at several airports across the country. The goal of this step was to understand at the most basic level those components necessary for maintenance of safety with respect to the runway system. The author visited several airports, of vastly different sizes, operations, and locations. Airports include Boston Logan International Airport (BOS), Charlottesville Albemarle Airport (CHO), Charlotte Douglas International Airport (CLT), Palm Beach International Airport (PBI), Ronald Reagan National Airport (DCA), San Francisco International Airport (SFO), and Washington Dulles International (IAD). The diverse nature of the airports helped ensure that common characteristics relating to runway safety were likely the result widespread tendencies rather than unique features.

An important characteristic and necessary component in maintaining runway safety among airports, evident from the early stages, was *clear and effective communication* between the many parties responsible for operations on airport grounds. Both monitoring of air traffic communications and observation of interaction among airport ground employees were used to gauge and confirm the importance of this characteristic. A rapid level of communication and interaction was present at all airports. The correct interpretation and execution of commands appeared essential in maintaining runway safety.

An additional aspect of airport operations which became evident through observation was the prevalence of vehicles on airport grounds. The type and purpose of these vehicles varied greatly, but it was clear that runway safety was dependent on the *safe and responsible operation of these ground vehicles*. All airports visited, regardless of size, had numerous ground vehicles operating simultaneously with airplanes on grounds.

The identification of these two key components was an important foundation for the selection of factors to be described later. Further analysis will support the inclusion of these components in the final approach.

3.3 Expert elicitation

Having identified two potentially relevant factor components through observation, the author contacted airport officials from both airports visited and additional airports to help in a further examination. The goal of this step was two-fold, to gain a better understanding of the relevance of communication and ground vehicles in runway safety, and to investigate other, or alternative, factors of importance.

Airport operations managers are vital in ensuring airport runway safety and due to their position are intimately familiar with the many aspects of daily airport operations. They interact frequently with the airport workforce, the FAA and other airport entities. Their firsthand experience and knowledge can be useful in gaining a further understanding of the human and cultural aspect of runway safety. Airport operations managers from a variety of airports, including, Dulles International Airport, Miami International Airport, Atlanta-Hartsfield International Airport and Los Angeles International Airport, were contacted and provided both general feedback and specific insight relating to human and cultural factors and runway safety.

Operations managers confirmed the importance of clear and effective communication. In many cases, at least part of the miscommunication issues stemmed from language heterogeneity among those on airport grounds. A lack of English proficiency can impact communication tremendously. In fact, in several instances, it was noted that English was not the primary language of the majority of the ground workforce. The presence of this type of language diversity is likely to have an impact on communication. Given the rapid nature of communication on airport grounds, a deep understanding of the English language is necessary.

Additionally, nearly all the operations managers cited a lack of safe and responsible ground vehicle operations as a significant factor in runway incursions. The reason for ground vehicle based incursions varied, from lack of attention due to the repetitive nature of the driving to a fundamental misunderstanding of the airport regulations. Operations managers also noted the effect of complex runway geometry in compounding the problem.

The conversations with airport officials were valuable and helped to gain a more thorough understanding of the threats to safety of runway systems. A confirmation of preliminary observation and study helped confirm the role of human and cultural factors, specifically effective communication and ground vehicle operations.

3.4 English proficiency as a factor

It is common for native speakers of English to misinterpret the messages of others. An addition of those with limited knowledge of English can compound the problem. (Krivonos, 2007).

While English is the official language of aviation, system safety remains vulnerable to errors arising from differences in language and interpretation. Safety in many critical moments is dependent on successful communication between individual parties. It has been noted that a lack of proficiency in the English language has led directly to many accidents and other unsafe acts (Prinzo *et al.*, 2010). In fact, some of the most deadly accidents in aviation history have been allegedly due to a lack of comprehension with respect to the English language (Tajima, 2004). In several cases a single individual, such as a crew member or grounds employee, was the source of the error resulting from a lack of English proficiency.

Steps have been taken to help improve the maintenance of high English proficiency levels among those involved in aviation. There are challenges in both the design and implementation of English proficiency standards, and it is important to recognize the mutli-layer nature of English proficiency, which the International Civil Aviation Organization (ICAO), a branch of the United Nations, presented in 2009. The ICAO identifies six primary areas associated with English proficiency: Pronunciation, Structure, Vocabulary, Fluency, Comprehension, and Interactions. These six areas are used to aid in proficiency evaluation per the ICAO Language Proficiency Rating Scale. The FAA has acknowledged full acceptance and support of the proficiency standards presented by the ICAO (2004).

While efforts made by the ICAO to help improve English proficiency represent a major step in increasing aviation safety, several threats to both the validity and the effectiveness of the standards still exist. Several of these issues are presented below.

Reviews of English proficiency testing methods often offer harsh criticisms of current practices, citing a lack of meaningfulness and reliability (Alderson, 2010). It has been shown that typical tests can neglect to assess the ability of an individual to communicate in more aviation based varieties of English. The type of English commonly used in aviation can include partial phrases, abbreviations or incomplete sentences (Campbell-Laird, 2004). The types of changes to testing standards suggested by studies vary from minor adjustments to complete restructuring. Suggestions include continual testing to ensure maintenance of proficiency and expansion of testing requirements to cover additional varieties of English (Mathews, 2004).

In addition, studies also show that a lack of native sense regarding intricacies of the English language can be cause for mistakes (Tajima, 2004). It is also noted that a lack of situational awareness with respect to language can also lead to miscommunication and subsequent incidents (Tajima, 2004). To further compound the problem, it has been shown that misunderstandings in aviation increase significantly when multiple parties are non-native English speakers (Tiewtrakul and Fletcher, 2010).

A final concern regarding current proficiency standards is a lack of testing and regulation among non-pilot or air traffic control (ATC) personnel. Although the grounds workforce interacts frequently with other parties, including ATC personnel, while operating on airport grounds, they are not held to the same proficiency standards. The international requirements developed for pilots and ATC personnel simply do not apply (Cutting, 2012). It is therefore likely that levels of miscommunication among the ground workforce may be the same if not greater than those among other airport personnel.

3.5 Ground vehicle operations as a factor

In addition to English proficiency, the FAA and other aviation organizations are beginning to recognize the critical role of ground vehicles in ensuring runway safety. While the prevalence of vehicles on airport grounds is often varied, it represents a threat due to their frequent interaction with airplanes, runways and other active airport zones. Often overlooked due to their relative size and simplicity, ground vehicles have not been the focus of efforts to improve runway safety. However, growing complexity of airports as well as an increased presence of vehicles on grounds has led to a renewed interest in understanding the impact of ground vehicles. This section will investigate the role ground vehicles play in runway safety and help support the inclusion of a ground vehicle based factor in the ultimate analysis.

The National Transportation Safety Board (NTSB), which acknowledges ground risks as the greatest threat to aviation safety, cites ground vehicles as a significant part of the problem (FAA, 2007). Recent reports, sponsored by the FAA, have focused on methods for reducing ground vehicle related incidents. A 2011 report cites the intent of the FAA to reduce incidents related to ground vehicle operations at airports (FAA, 2011).

Additional reports published by the FAA also focus on the necessity of reducing the potential for ground vehicle deviations. Several instances of ground vehicle error as cause for incident are highlighted, of particular interest, however, are those resulting from probable speeding and lack of attention by the driver (ACI, 2009). Additionally, cases in which ground vehicle operators disregarded designated runway routes in favor of shortcuts as a matter of convenience should also be noted. In these types of cases, operator, or human, error is likely the root cause of the incident.

Other studies have attempted to more specifically quantify the effect of ground vehicles on runway safety. Some estimates suggest that up to twenty percent of all runway incursions can be directly attributed to ground vehicle operations (Young and Vlek, 2009). These incidents also come at a high price, as estimates also suggest a multi-billion dollar annual loss due to ground vehicle related incidents (Costello, 2007). These types of incidents have led to increased interest in development of vehicle tracking devices and methods, in an effort to reduce the rate at which they occur. Electronic tracking systems and enhanced surveillance techniques are among many of the proposed methods for reducing ground vehicle related incidents (Schonefield, 2012).

Having identified two mechanisms with seemingly strong influence on runway safety, additional steps should seek further investigate the potential root causes for the factors, methods for objective quantification, significance with respect to runway safety, and incorporation into the existing framework.

3.6 Incursion database review and analysis

The FAA maintains a database of all recorded runway incursions, as well as comprehensive information regarding each incident. This database is a valuable tool and can be used effectively for deeper analysis of specific runway incidents. Due to strict procedural guidelines, the information is not only accurate, but thorough and detailed. These characteristics will aid efforts to deeper understand possible root causes.

While all categories included in the database are useful, of particular interest is a detailed narrative describing each incursion. This narrative can help in an evaluation of the possible contributors to the incursion. The following narratives have been extracted from the FAA databases for Fiscal Year 2008, 2009, 2010, and 2011. Although it is difficult for this qualitative assessment to offer absolute conclusions, it can certainly further support English proficiency and ground vehicle operations as factors.

Numerous incidents can be traced to errors arising from language based miscommunication, several instances are highlighted below.

The following incident was the result of a misunderstanding resulting from a partial misinterpretation of a runway command. The narrative suggests that a simple word substitution was likely to blame. Additionally, the report notes that one party was communicating in heavily accented English. It is likely that this language related aspect contributed to the miscommunication and subsequent incident.

Partial closure of Taxiway Alpha between Charlie and Bravo necessitates back taxi when departing Runway 20. N156BB, SOCATA TOBA, was issued "Runway 20 at Charlie, taxi via Alpha, expect a back taxi from tower for full length departure". Pilot read back "Runway 20 via Alpha, Charlie and back taxi to full length (call sign)". ***Pilot had a heavy accent and read back was interpreted as correct****. The SOCATA TOBA then entered Runway 20 and proceeded to back taxi…*

A similar language barrier is again the likely cause of the incident described below. Difficulties in understanding and interpretation led to confusion amongst both parties. The narrative specifically notes the issue of language.

A IAI WW24, inbound on ILS approach Runway 2, was instructed by ZLC ARTCC to contact tower at the FAF, 6.8 miles from runway threshold. Snow removal was in progress (2 vehicles on and off the runway doing intersections) at the departure end of Runway 2 with one vehicle clear of the runway at B1 and the other clear of runway at B2 intersection but both were within the runway safety area. The first transmission received from the pilot was over the threshold with confusion by ATCT as to the position of the WW24 ***due to a language problem on the part of the pilot****…*

Again, an apparent non-familiarity with English likely served as the root cause of the following incident. Despite clear transmission between both parties, an action was taken in direct conflict with commands given and received.

> *N49439, Cessna C152, solo flight by a* ***foreign student*** *pilot, was instructed by Ground (GC) to taxi via left on Bravo, right on Charlie and hold short of Runway 32 on Charlie. Pilot read back the hold short instructions. GC then advised the C152 to give way to a jet crossing left to right and did not reissue the hold short instructions. The pilot read back the give way instructions…The C152 had just crossed the hold bars but stopped prior to the runway edge line. The* ***student pilot stated that he thought the give way instructions meant follow the aircraft****…*

In addition to incidents with a lack of English proficiency as probable root cause, the databases contain numerous records of ground vehicle operations as likely contributors. These incidents involve both non airport and airport specific vehicles and are often the result of negligence, failure to adhere to rules, and irresponsible driving tendencies.

An incident involving a private vehicle was attributed to speeding and failure to correctly adhere to airport regulations.

> *A vehicle (black SUV) crossed Runway 27 at Taxiway A2 north to south* ***without authorization*** *and conflicted with a Cirrus SR22 on takeoff roll full length same runway. The SR22 rotated normally near Taxiway A3 as the* ***vehicle crossed at a high rate of speed.*** *The vehicle cleared the runway and the SR22 continued departure passing the A2 intersection at approximately 300 feet AGL*

Irresponsible operation of non-airport based vehicles on airport grounds is also a significant issue. Vehicles aiding in maintenance efforts are often operated in an unsafe manner. Careless and potentially dangerous behavior is not uncommon from operators of these vehicles.

> *Two contractor vehicles (pick-up truck and front end loader) were observed by a Port Authority vehicle* ***crossing Runway 17C at Taxiway ER without authorization*** *... The vehicle operator told the Port Authority that they were being escorted around the south end of 17C and* ***saw a shortcut, Taxiway ER, and decided to take it.***

Unsafe operation of airport-based vehicles is also a concern. A variety of ground vehicles, from baggage carts to refueling trucks have been a contributing factor to runway incidents.

> *An airport fuel truck* ***drove around construction barricades*** *onto Taxiway Foxtrot between Alpha and G3* ***without clearance****.*

Chapter summary

A thorough review of the incursion database, airport observation, and expert elicitation further suggests the importance of English proficiency and ground vehicle operations in runway safety. Additional steps in the following chapter will focus on methods for quantification of the human and cultural factors and inclusion into existing frameworks.

4. Technical Approach

4.1 Chapter Overview

It is necessary for a new class of human and cultural factors to be quantitatively represented for inclusion into the existing framework. The quantification of these factors presents a challenge, as English proficiency and ground vehicle operations are somewhat qualitative in nature. Additionally, there are no existing methods by which these factors can be assessed. This chapter will propose a new method for quantification that can be objectively and uniformly utilized for all of the airports in nine FAA regions. Section 4.2 provides a method for the quantification of the English proficiency level. This section will focus on the English proficiency of the population surrounding the airport and the relevant application of this demographic information. Section 4.3 provides a method for quantification of ground vehicle operations. Again, the information from the population surrounding the airport is utilized. Section 4.4 provides an exploratory analysis of the relationship between the newly quantified factors and historical incursion data. Section 4.5 describes the existing rank-ordered prioritization method and identifies the effect of human and cultural factors. Section 4.6 describes a newly introduced ratio based prioritization framework and identifies the effect of human and cultural factors.

Development of the two demographic factors in this chapter is by no means representative or comprehensive of the effort that will be needed to bring human and cultural considerations to the prioritization of runway safety audits. The two factors are best viewed as an example or initial step toward the more complete goal. The roadmap of the technical approach to select and demonstrate the use of demographic factors for prioritizing airports for runway safety audits in shown in Figure 1.

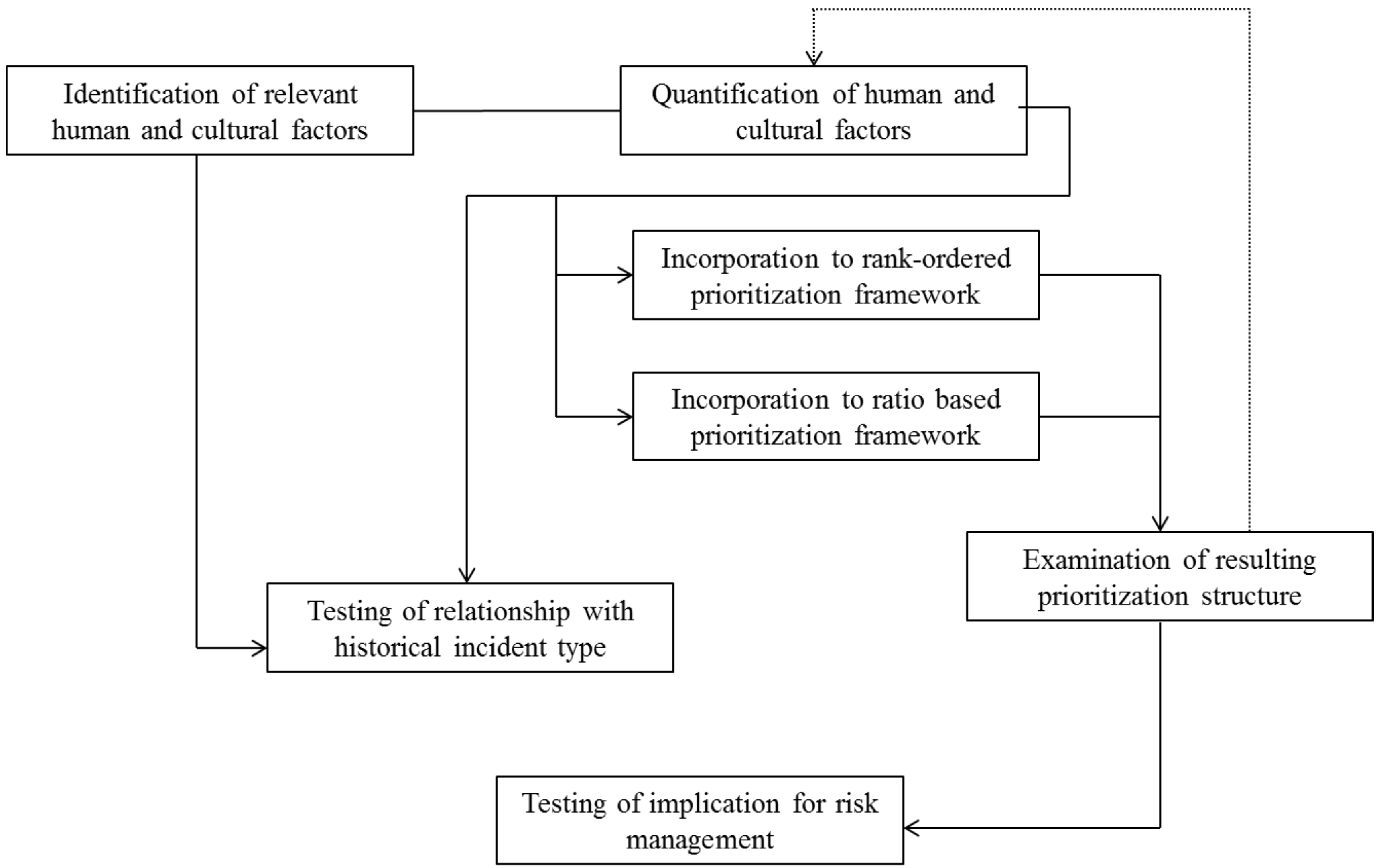

Figure 1. Roadmap of technical approach to select and demonstrate the use of demographic factors for prioritizing airports for runway safety audits

4.2 English proficiency quantification

Identification of English proficiency is useful in two primary ways; it can bring attention to airports where both miscommunication involving ground workers and miscommunication involving aircraft crews is potentially a higher risk. For the prioritization effort, this thesis will use the language characteristics of the population surrounding an airport to better understand the levels of English proficiency on airport grounds.

This proposed approach can help account for a lack of direct data with respect to airport workforce demographics. The airport workforce is comprised of individuals employed by a variety of entities. This prevents a lack of centralized information, which, even if available, would likely poorly describe workforce demographics. Non-uniformity in collection and certain withholding of information can often negatively affect the maintenance of such demographic data. United States census data, which will be utilized in this approach, can be a more effective means for understanding the workforce demographics. Detailed language information found in the census is especially useful.

The 2010 United States census provides detailed language information that can be used to determine the English proficiency of the population surrounding airports. The census allows respondents to describe their ability to speak English at one of four levels. On the 2010 census, question 14c asks respondents, "How well do you speak English?" The four choices are: *very well, well, not well or not at all*. Of particular interest are those who speak English not well or not at all. Identifying the segment of the population who speaks English not well or not at all helps provide a better understanding of the language heterogeneity within the population.

ArcGIS software can be a valuable tool for identifying the language characteristics of the surrounding populations. Importing 2010 United States census data and the geographic coordinates of an airport can allow for a collection of the total number of those who speak English not well or not as well, as well as the overall population, within a twenty mile radius of the airport. For the purpose of this study, there is only a need to understand the characteristics of the population who is of working age. Therefore the data collection process was further refined to only include the population aged eighteen to sixty four. A screenshot of the ArcGIS census data page can be found in the appendix.

Sample results for a large collection of airports are shown in Table 2. The airports selected are geographically and operationally diverse and will used in additional analysis. A visual representation of the geographic diversity of the airports is presented in Figure 2.

Table 2. Non-English proficiency rates for selection of geographically, operationally and demographically diverse airports

Airport	*Surrounding Population*	*Non-English Proficient*	*Non-English Proficiency Rate*
Atlanta Hartsfield	1,329,787	65,996	4.96%
Baltimore-Washington	1,599,681	32,966	2.06%
Charlotte/Douglas	744,102	265,52	3.57%
Cincinnati/Northern Kentucky	796,119	6,400	0.80%
Dallas/Ft Worth	2,015,024	209,555	10.40%
Denver	739,183	54,178	7.33%
Detroit Metro	1,381,540	33,976	2.46%
Ft Lauderdale/Hollywood	1,728,688	206,183	11.93%
George Bush Houston	1,426,756	166,229	11.65%
Honolulu	539,776	27,676	5.13%
Indianapolis	790,931	13657	1.73%
Kansas City	489,962	15,229	3.11%
Boston Logan	1,844,275	81,652	4.43%
Louis Armstrong New Orleans	691,283	11,675	1.69%
Memphis	655,718	11,308	1.72%
Miami	1,689,247	306,017	18.12%
Minneapolis	1,503,522	43,907	2.92%
Newark	7,144,030	890,386	12.46%
O'Hare	3,400,728	325,861	9.58%

Orlando	856,388	41,819	4.88%
Phoenix Sky Harbor	1,769,773	148,446	8.39%
Portland	1,103,791	48,880	4.43%
Raleigh-Durham	684,604	27,009	3.95%
Salt Lake City	665,723	26,371	3.96%
San Francisco Intl	1,861,111	181,017	9.73%
Syracuse Hancock	359,200	4,320	1.20%
Tampa	1,184,745	41,743	3.52%
Washington Dulles	1,221,048	73,510	6.02%
National Average	4.52%	Selected Average	5.79%
Standard Deviation	6.06%	Selected Standard Deviation	4.25%

Statistics are gathered for a twenty mile radius surrounding each airport. The population consists of working age individuals (Ages 18-65).

Figure 2: Location of geographically, operationally and demographically diverse airports for use in human and cultural factor analysis

Miscommunication involving flight crews has been shown to have a significant effect on runway incursions (Jones, 2003). Aviation based studies, as well as a review of the FAA incursion database help to further confirm the importance of clear and effective communication. A demonstrated cause for these types of incidents is a prevalence of language diversity. The extent of this language diversity involving flight crews is often associated with prevalence of international operations at an airport. Figure 3 below highlights the strong linear correlation between the language heterogeneity of the population surrounding an airport and the international flight rate of the airport. This analysis is shown for the collection of geographically, operationally and demographically diverse airports. An R^2 value of 0.7736 further confirms the strong correlation.

In addition to the miscommunication involving flight crews, miscommunication involving ground crews can also present challenges. Ground crew members must interact frequently with ATC personnel and other parties, and misunderstanding stemming from language diversity can be a threat to runway safety. Airports with higher language heterogeneity in the surrounding population may be more likely to have higher rates of language heterogeneity on airport grounds. The ground workforce is comprised of individuals drawn from the surrounding population and may be likely to share many of the characteristics found in the surrounding population.

English proficiency rates are useful in understanding the likely language characteristics of both flight based and ground based crews. A uniform and objective technique is useful as it allows for efficient collection among the large number of airports. This method will allow for the incorporation of the English proficiency factor into the prioritization framework. The next step involves quantification of ground vehicle operations.

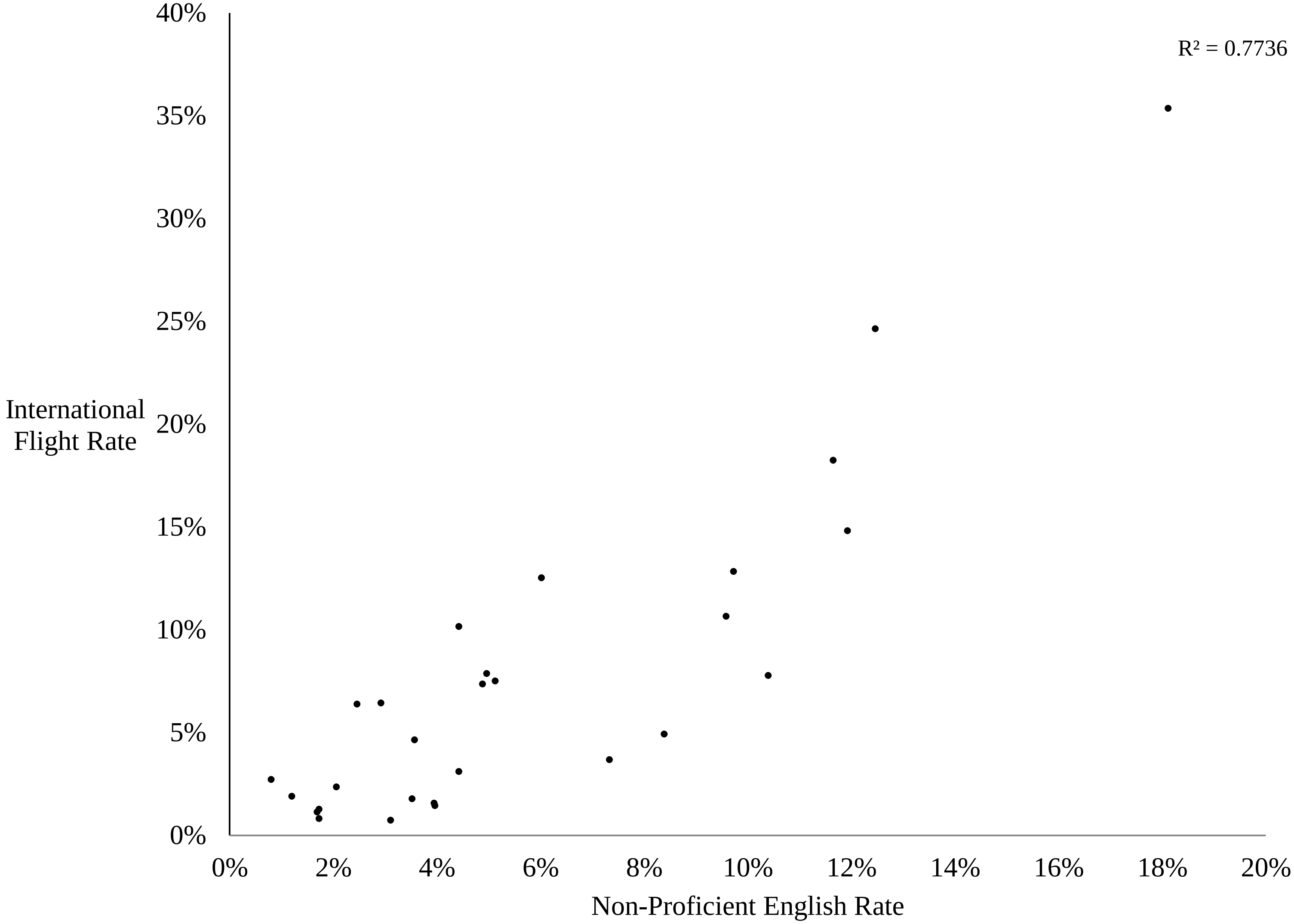

Figure 3: English proficiency rate and international flight rate correlation for selection of geographically, operationally and demographically diverse airports
(Airports included shown in Table 2)

4.3 Ground vehicle operation quantification

In order to address ground vehicle operations, it is necessary to account for both non-airport based and airport based vehicles operating in runway areas. Incidents have been caused by the unsafe operation of both types of vehicles. It is therefore important to identify a process that will help understand the operation of both types of vehicles.

Challenges similar to those presented when quantifying English proficiency appear when attempting to quantitatively represent ground vehicle operations. A lack of centralized data, as well as the highly subjective nature of defining various levels of ground vehicle operator performance will necessitate an approach similar to that used for English proficiency quantification. Driving characteristics of the population surrounding an airport will be used for an understanding the characteristics of vehicles on airport grounds. The Fatality Analysis Reporting System (FARS) database will be utilized in this effort.

The FARS database, maintained by the National Highway Traffic Safety Administration (NHTSA), contains detailed information regarding every fatal automobile accident occurring on a public road in the United States. Due to the severity of the accidents, the information found in the database is both highly detailed and accurate. A screenshot of the FARS encyclopedia query page used in this analysis can be found in the appendix.

The FARS database is useful as it allows for an understanding of the driving habits of the population surrounding an airport. Ground vehicle operators on airport grounds will be both directly and indirectly drawn from this population. A higher rate of fatal accidents is likely to be associated with poorer driving habits, while a lower rate may be associated with more responsible driving habits.

A review of ground vehicle related incursions revealed a large percentage of incidents involved a commercial type vehicle. These types of vehicles are commonly found on airport grounds and the operator behavior of these types of vehicles is of particular interest. There are two primary ways in which accidents involving these specific types of vehicles can be isolated. The first approach utilizes the ability of the FARS encyclopedia to query accidents based on the type of vehicles involved. Selection of the vehicle types presented in Table 3 will highlight accidents of interest.

Table 3: Identification of relevant vehicles to model airport ground vehicles by code and body type

Vehicle Code	*Vehicle Type*
40	Cab Chassis Based (Includes Rescue Vehicle, Light Stake, Dump, and Tow Truck)
41	Truck Based Panel
42	Light Truck Based Motorhome (Chassis Mounted)
45	Other light conventional truck type
48	Unknown light truck type
49	Unknown light vehicle type (automobile, utility vehicle, van or light truck)
50	School Bus
51	Cross Country/Intercity Bus (Motor Coach)
52	Transit Bus (City Bus)
58	Other Bus Type
59	Unknown Bus Type
60	Step Van (>10,000 lbs. GVWR)
61	Single unit straight truck (10,000 lbs. < GVWR < or = 19,500 lbs.)
62	Single unit straight truck (19,500 lbs. < GVWR < or = 26,000 lbs.)
63	Single unit straight truck (GVWR < 26,000 lbs.)
64	Single unit straight truck (GVWR unknown)
66	Truck-tractor (Cab only, or with any number of trailing unit; any weight)
71	Unknown if single unit or combination unit Medium Truck (10,000 < GVWR < 26,000 lbs.)
72	Unknown if single unit or combination unit Heavy Truck (GVWR > 26,000 lbs.)
78	Unknown medium/heavy truck type
92	Farm equipment other than trucks
93	Construction equipment other than trucks (includes graders)

This filtering of data using the FARS database query system provides detailed information for all accidents involving a commercial type vehicle in standard excel format. The FARS query system does not allow for isolation of accidents within a specified region; therefore, the geographical coordinates provided for each fatal accident are utilized. In order to determine the number of fatal accidents within a twenty mile radius surrounding each airport the geographic coordinates of the accidents were compared to the geographic coordinates of the airport. A cumulative count of all commercial vehicle type accidents occurring within twenty miles of the airports, based on the coordinate comparison, was gathered.

While isolating commercial vehicle accidents based on vehicle type represented a significant first step, further research and investigation determined a more effective and perhaps accurate way of identifying commercial vehicle related accidents. Rather than isolating accidents by vehicle type, accidents were isolated if a driver of either vehicle involved in the accident was the holder of a commercial motor vehicle license (CDL). This method helps ensure that all commercial vehicle related accidents are isolated. The same process as described above was utilized to determine the number of accidents of this type within a twenty mile radius of each airport.

Having established an effective method for isolating relevant commercial vehicle license related fatal accidents in the population surrounding an airport, another challenged is presented, involving the most accurate technique for normalization of the data.

Three potential methods for normalization were investigated and are described in detail below.

The first method involved normalization by vehicle miles travelled (VMT). Using this technique would help account for large metropolitan regions were the number of commercial vehicle license related accidents was high simply due to a high volume of traffic and distance travelled. Although this method of normalization is most desirable, further investigation revealed that VMT data was only available at the county level, and could not be determined for specific regions i.e. a twenty mile radius around the airport. A simple examination of the geographical locations of several airports showed the normalization technique would not be viable.

An alternative method involved the use of emissions data as a normalization technique. An estimate of CO_2 emissions per square mile could be used once again account for areas with heavy congestion. However, similar to before, this data is only available at the county level and therefore would not be the most viable technique.

The final technique and the technique ultimately utilized, normalized CDL related fatal accidents by population. In order to follow FARS encyclopedia convention, the accidents were normalized by 100,000 population.

Sample results for the selection of geographically, operationally, and demographically diverse airports are shown in Table 4.

Table 4. Commercial vehicle driver's license related fatal accident rates for selection of geographically, operationally and demographically diverse airports

Airport	*CDL Related Fatal Accidents*	*Surrounding Population*	*CDL Related Fatal Accident Rate per 100,000 population*
Atlanta Hartsfield	155	2,476,876	6.26
Baltimore-Washington	64	2,633,244	2.43
Charlotte/Douglas	53	1,576,940	3.36
Cincinnati/Northern Kentucky	40	1,342,926	2.98
Dallas/Ft Worth	135	4,169,010	3.24
Denver	34	1,413,720	2.40
Detroit Metro	54	2,189,868	2.47
Ft Lauderdale/Hollywood	113	3,041,094	3.72
George Bush Houston	113	2,821,119	4.01
Honolulu	19	896,556	2.12
Indianapolis	56	1,407,146	3.98
Kansas City	26	844,029	3.08
Boston Logan	33	2,931,348	1.13
Louis Armstrong New Orleans	50	953,342	5.24
Memphis	100	1,153,674	8.67
Miami	104	3,011,208	3.45
Minneapolis	83	2,538,984	3.27
Newark	212	11,595,666	1.83
O'Hare	97	5,478,295	1.77

Orlando	71	1,696,072	4.19
Phoenix Sky Harbor	81	3,564,327	2.27
Portland	25	2,005,412	1.25
Raleigh-Durham	44	1,385,689	3.18
Salt Lake City	8	1,311,660	0.61
San Francisco Intl	52	2,899,699	1.79
Syracuse Hancock	17	590,538	2.88
Tampa	80	2,246,461	3.56
Washington Dulles	26	2,208,284	1.18

National Average	4.74	Selected Average	3.08
Standard Deviation	4.84	Standard Deviation	1.66

Statistics are gathered for a twenty mile radius surrounding each airport.

Having introduced and investigated a quantification method, relevant information was acquired for the airports in all nine FAA regions. Due to the regional makeup and structure of the FAA, it is important to provide results and analysis within the context of an FAA region. Resource allocation and other safety initiatives often occur within the framework of an FAA region. A map of the nine designated regions can be found in the appendix.

4.4 Exploratory analysis

It is important to examine the newly introduced factors with respect to previous runway incursion rates. This step will be significantly challenged by the sparse nature of the existing data as well as inherent error and bias likely found in the data due to the methods for reporting runway incursions. Additionally, the runway incursion rate can be significantly impacted by non-systemic events and represents just one method for measuring runway safety. As a result, for the purpose of this study, the exploratory analysis will be used to ensure a negative linear correlation does not exist between the human and cultural factors and the runway incursion rate. Results are shown below for the collection of nearly thirty airports previously identified, as well as the nine FAA regions.

A visual inspection of the above relationships, as well as low R^2 values, will confirm a lack of negative linear correlation between the human and cultural factors and previous incursion rates. Again, the sparse nature of the data prevents definitive conclusions with respect to a causal analysis; however, the factors cannot be eliminated based on their relationship with previous incident rates.

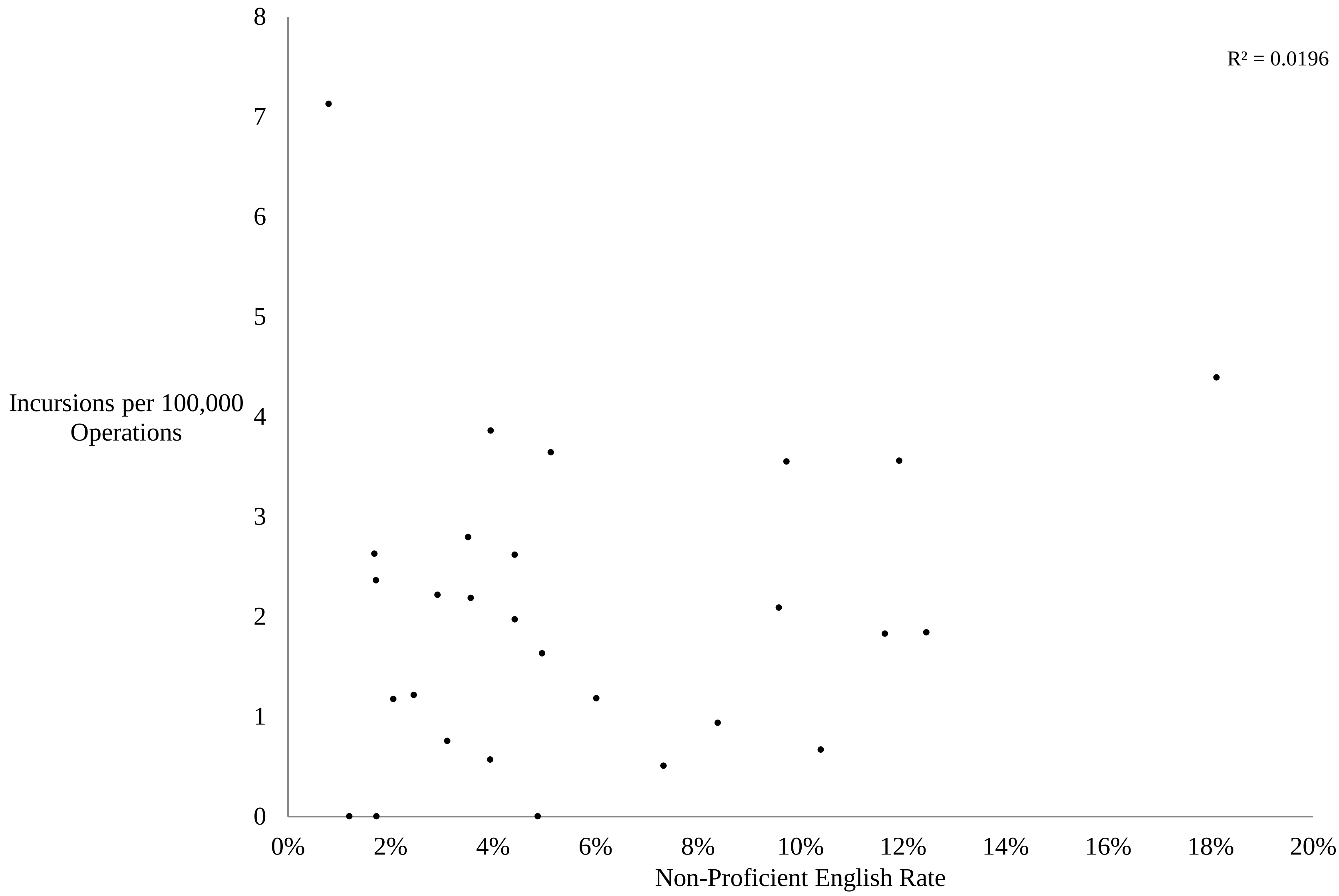

Figure 4: English proficiency rate vs. historical incursion rate – Selected geographically, operationally and demographically diverse airports

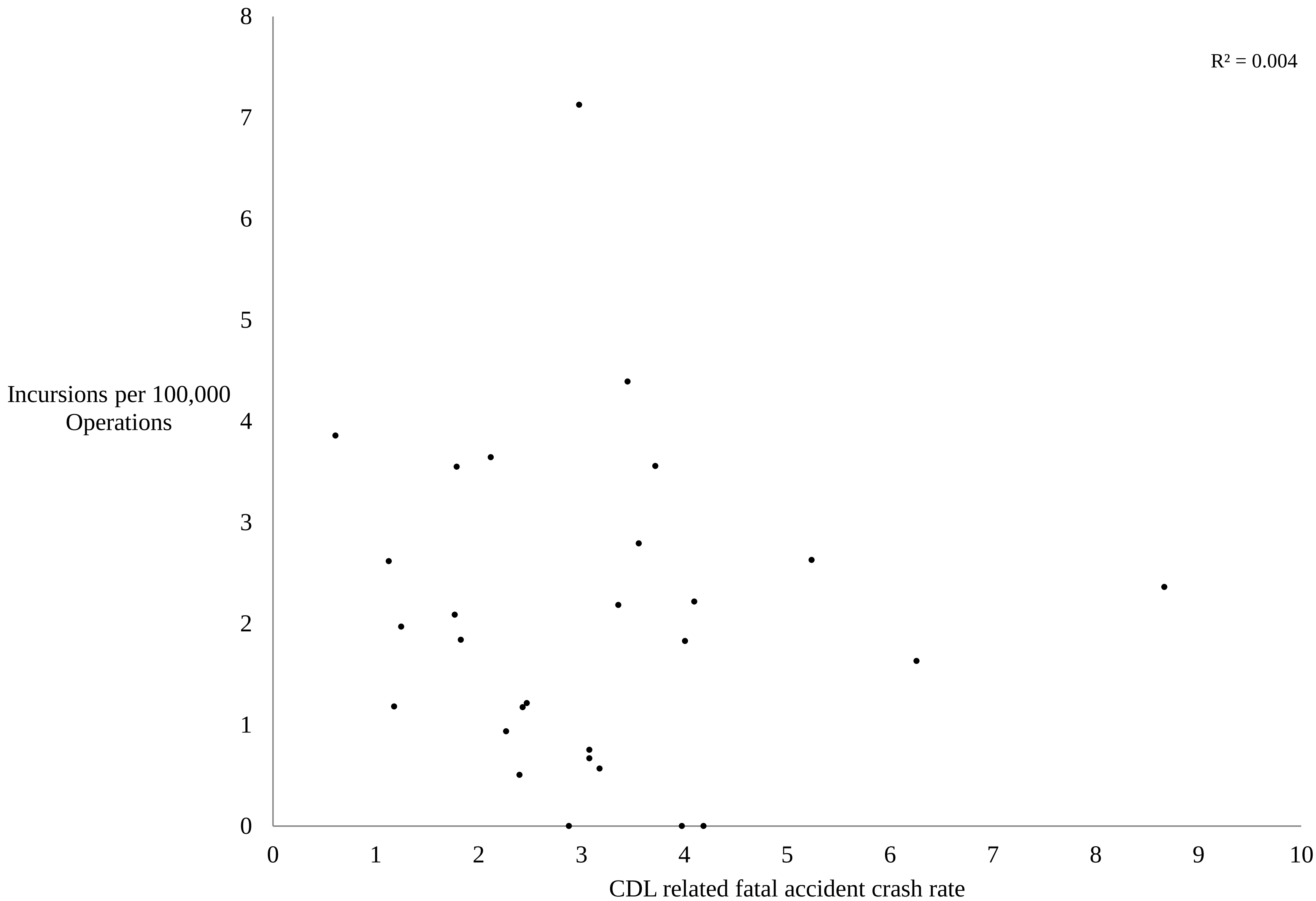

Figure 5: CDL related fatal accident rate vs. historical incursion rate – geographically, operationally and demographically diverse airports

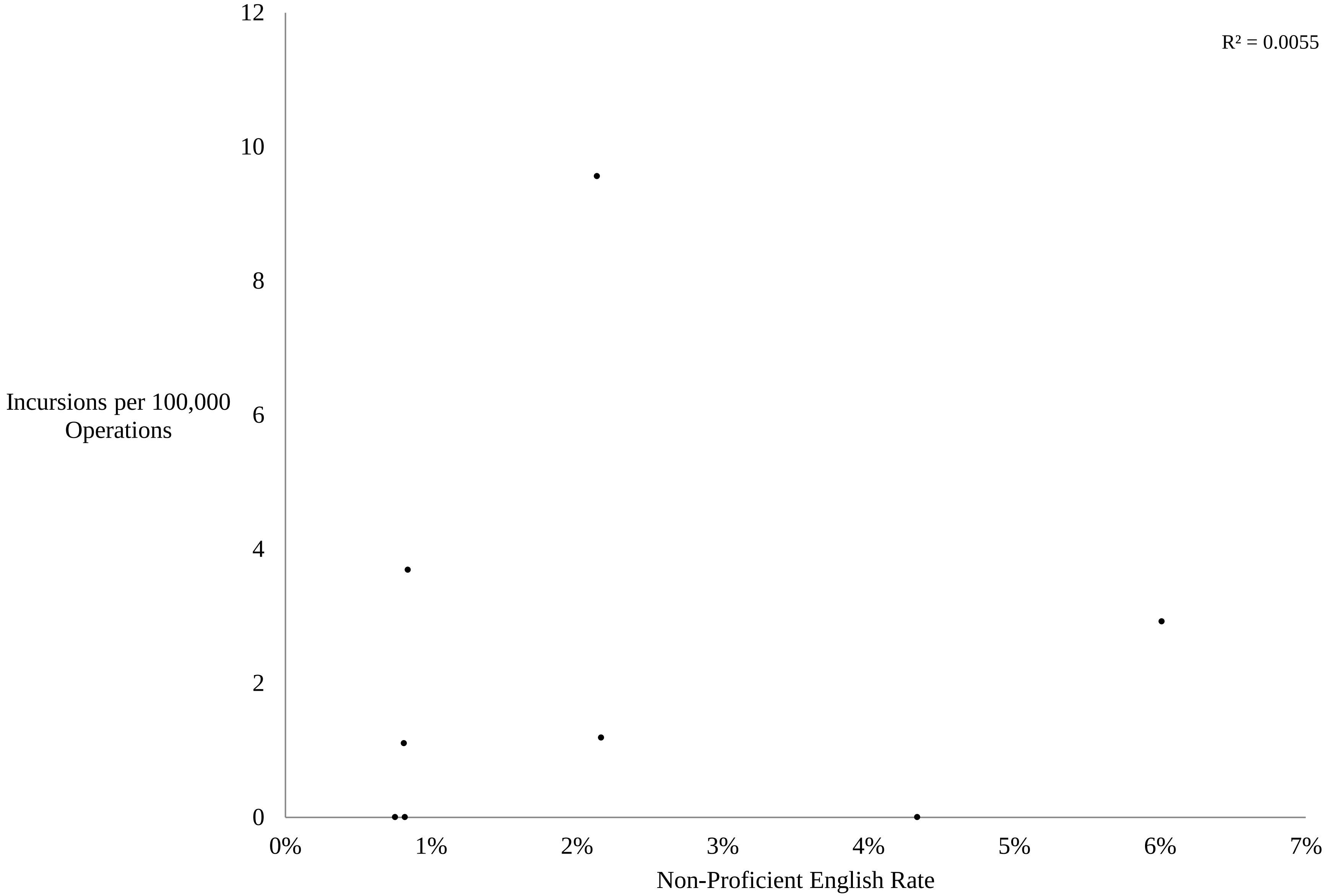

Figure 6: English proficiency rate vs. historical incursion rate – Alaska Region

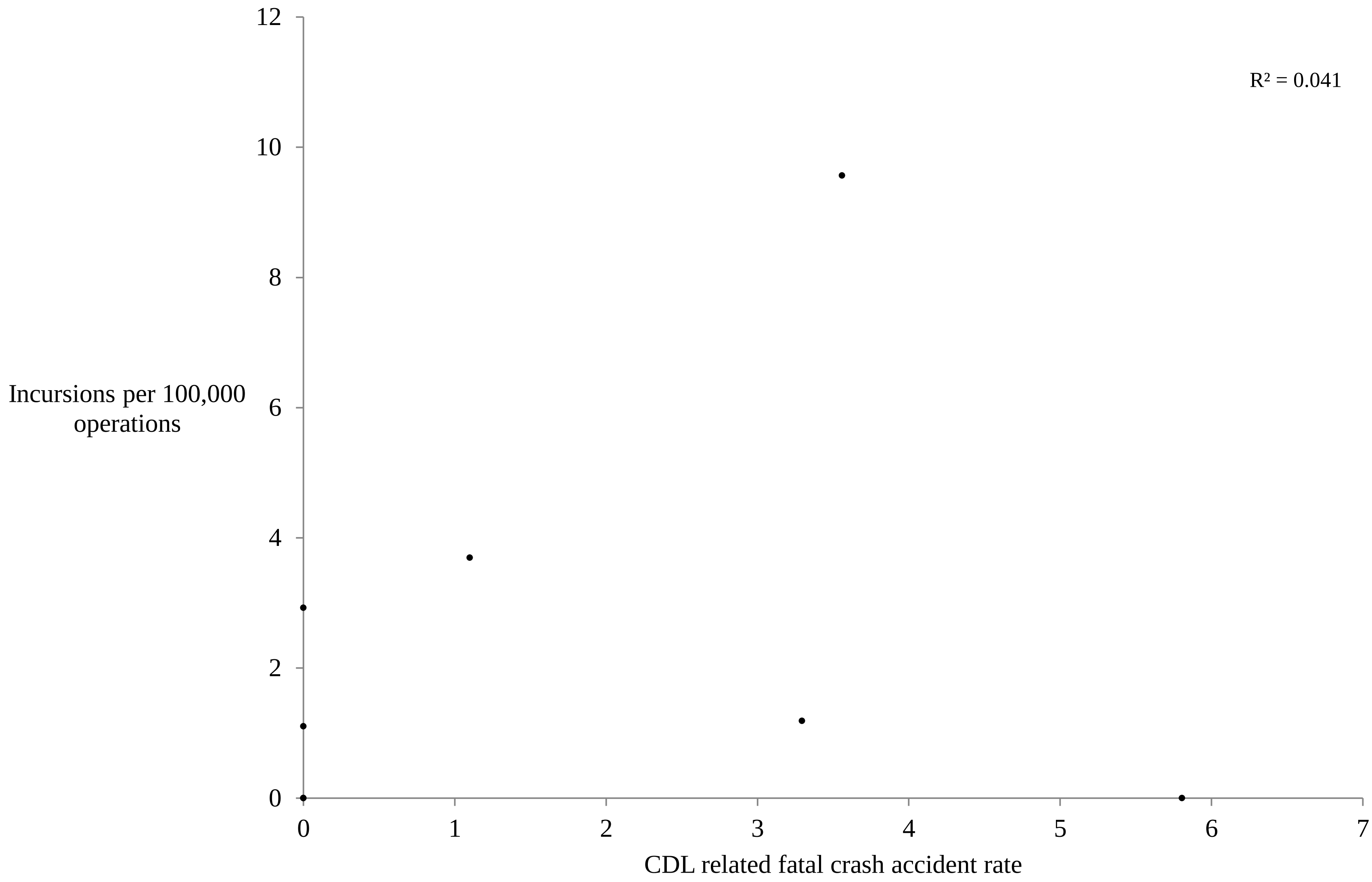

Figure 7: CDL related fatal accident rate vs. historical incursion rate – Alaska Region

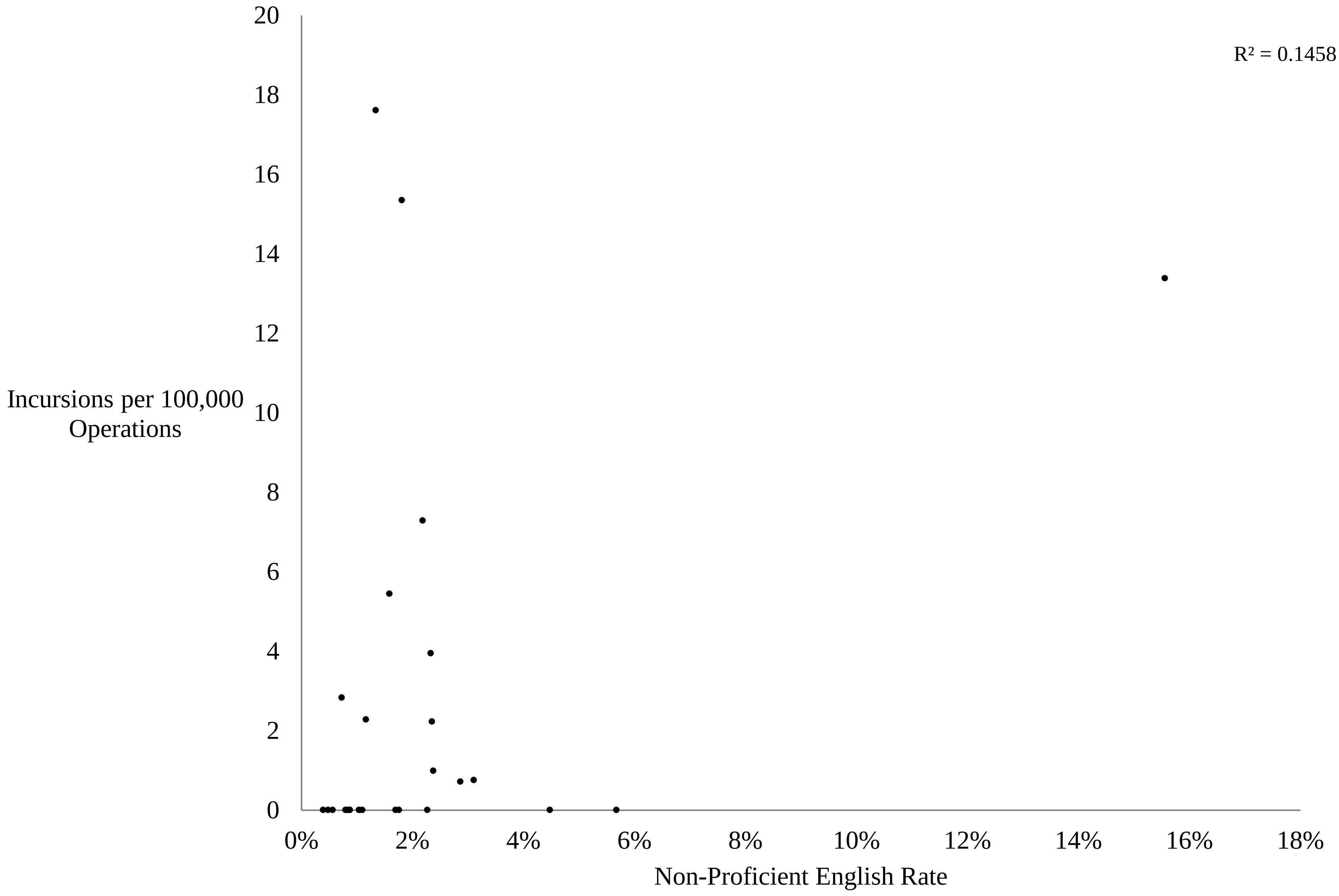

Figure 8: English proficiency rate vs. historical incursion rate – Central Region

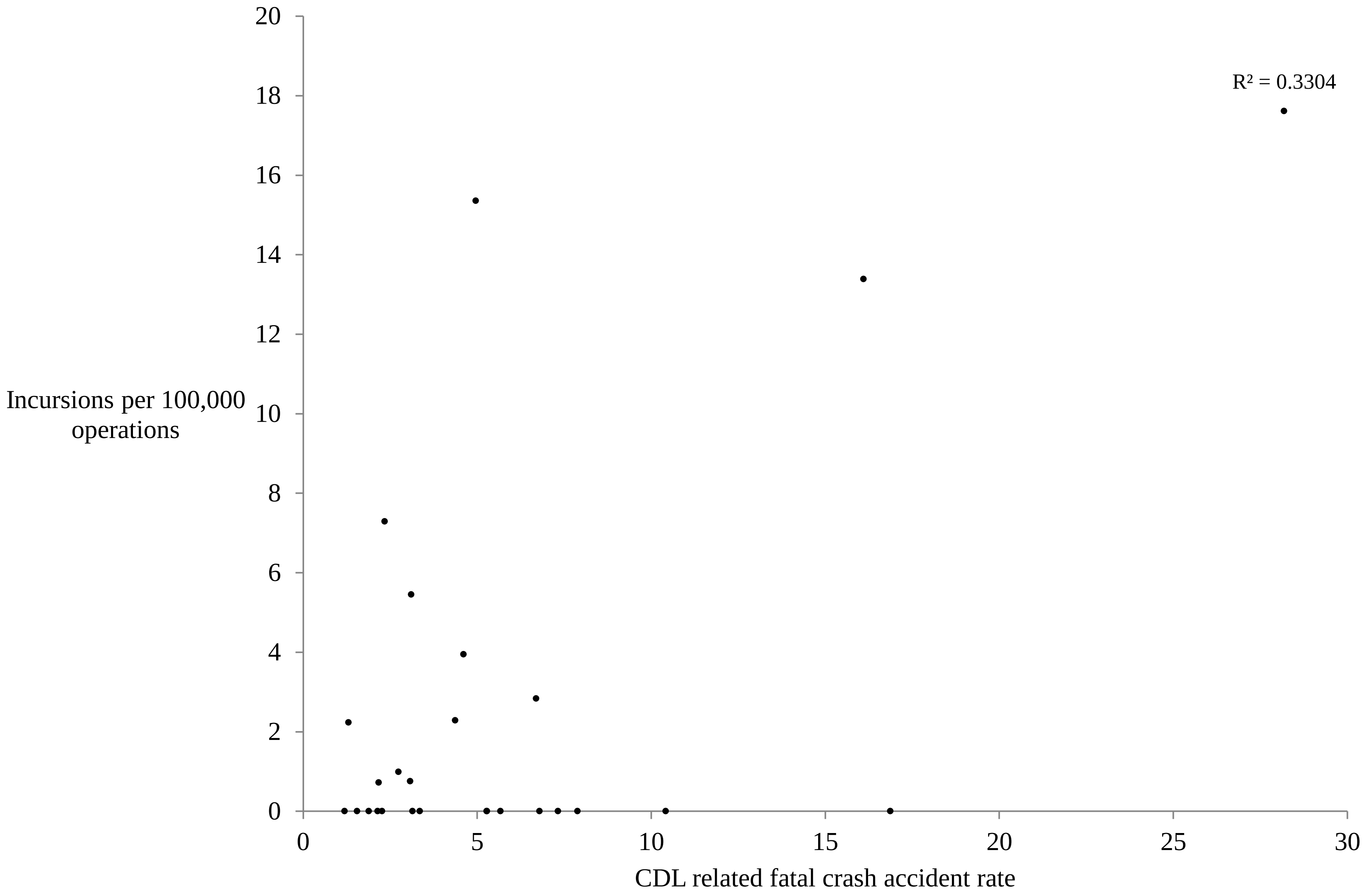

Figure 9: CDL related fatal accident rate vs. historical incursion rate – Central Region

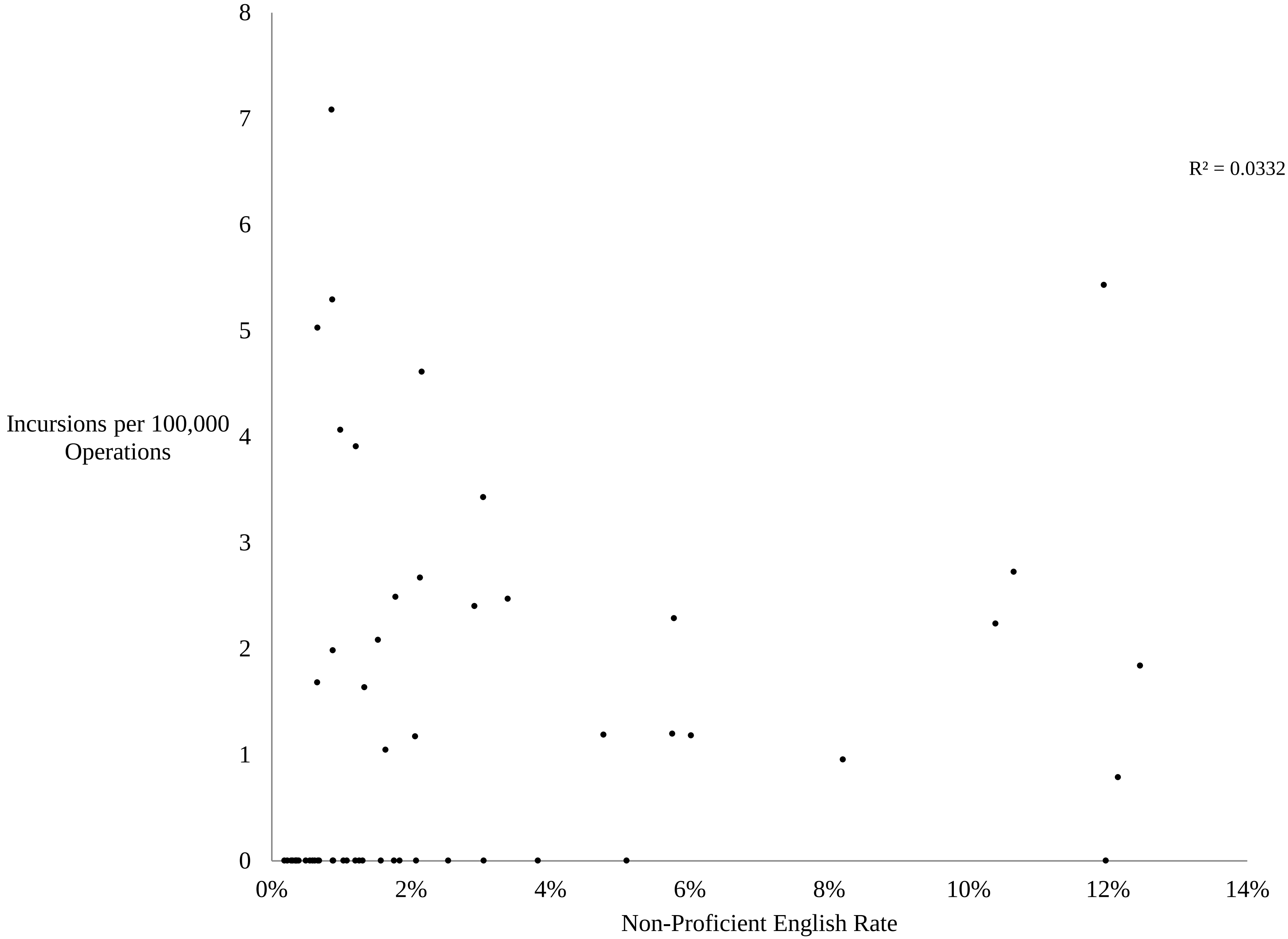

Figure 10: English proficiency rate vs. historical incursion rate – Eastern Region

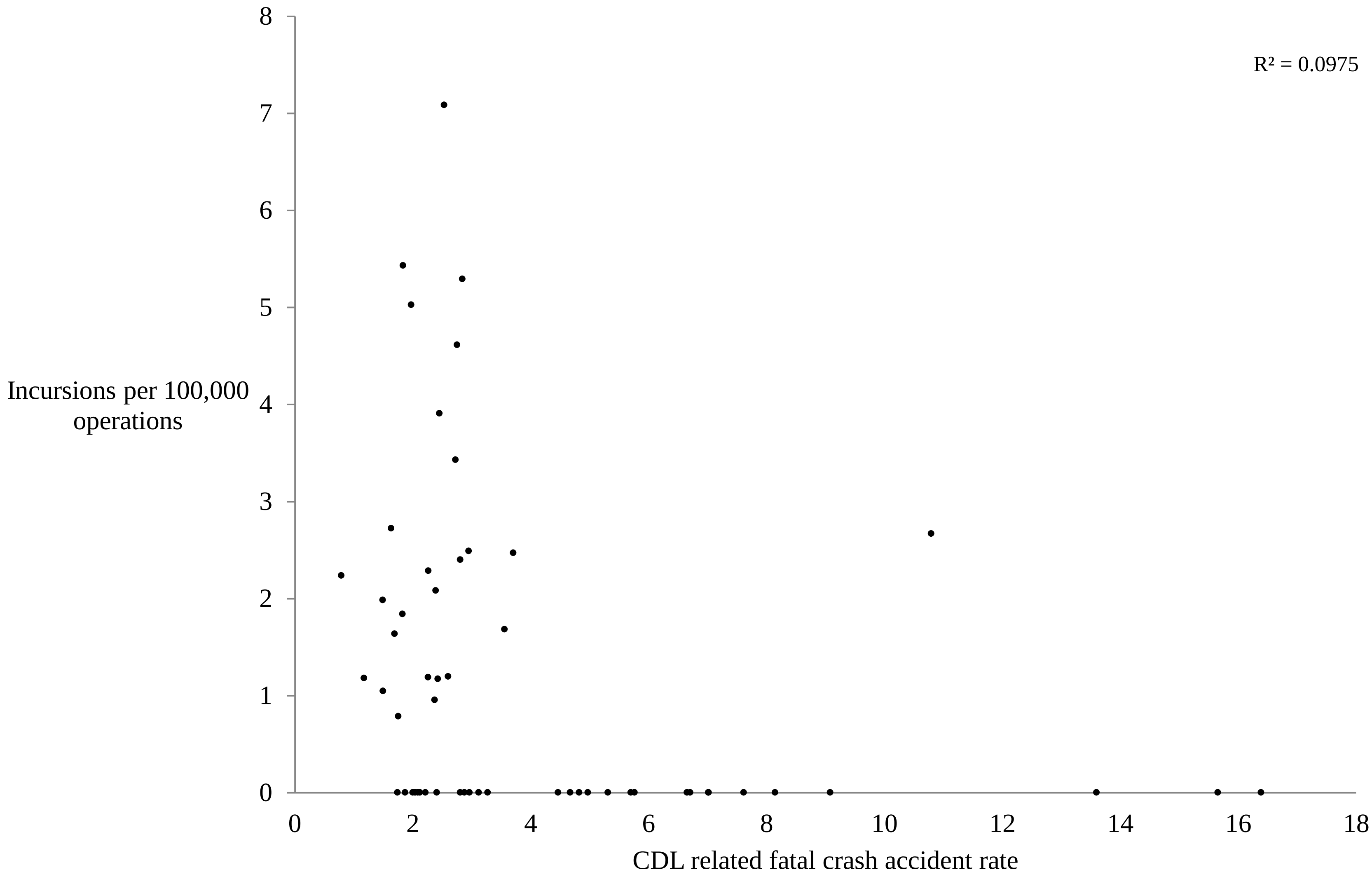

Figure 11: CDL related fatal accident rate vs. historical incursion rate – Eastern Region

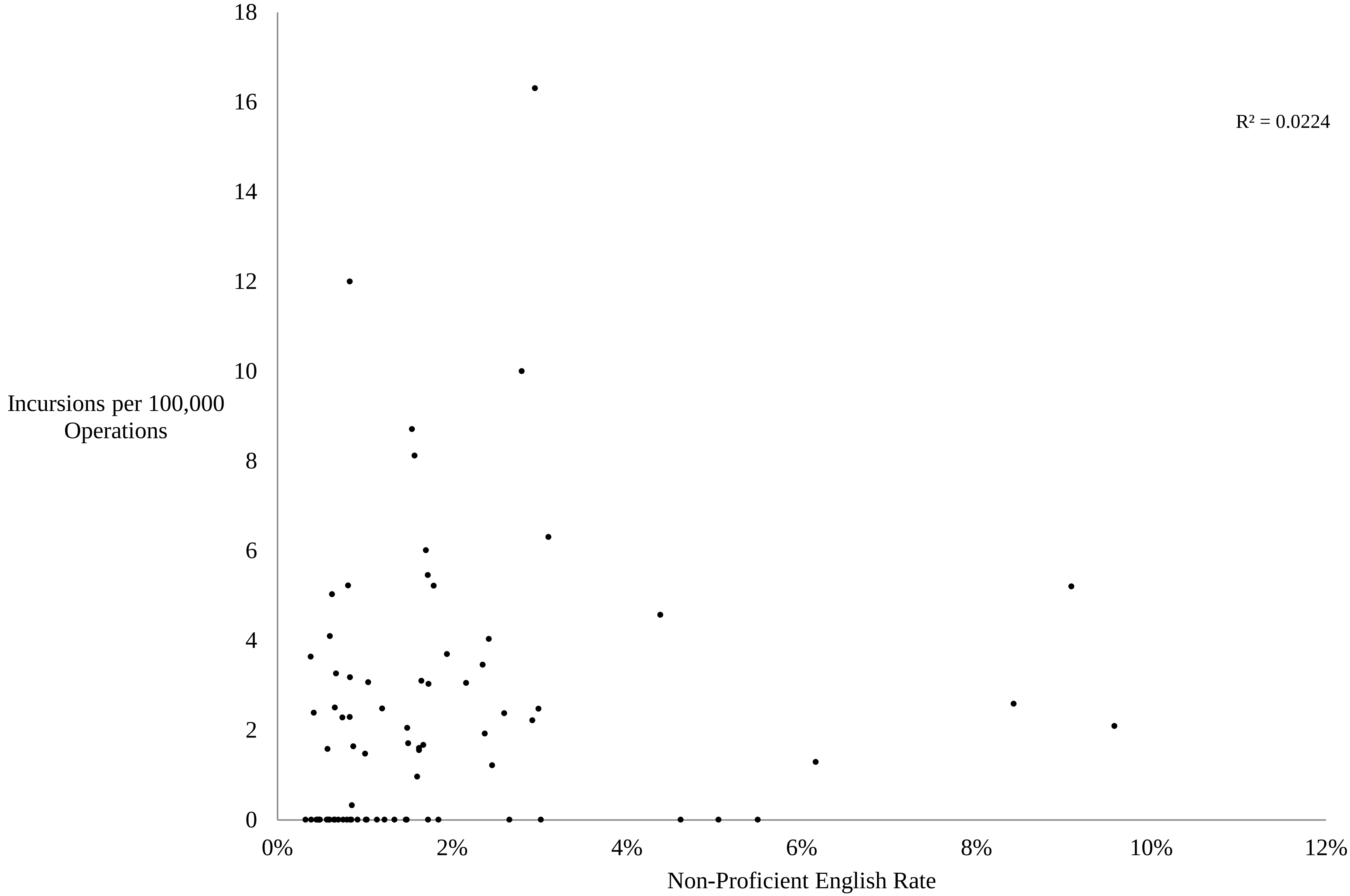

Figure 12: English proficiency rate vs. historical incursion rate – Great Lakes Region

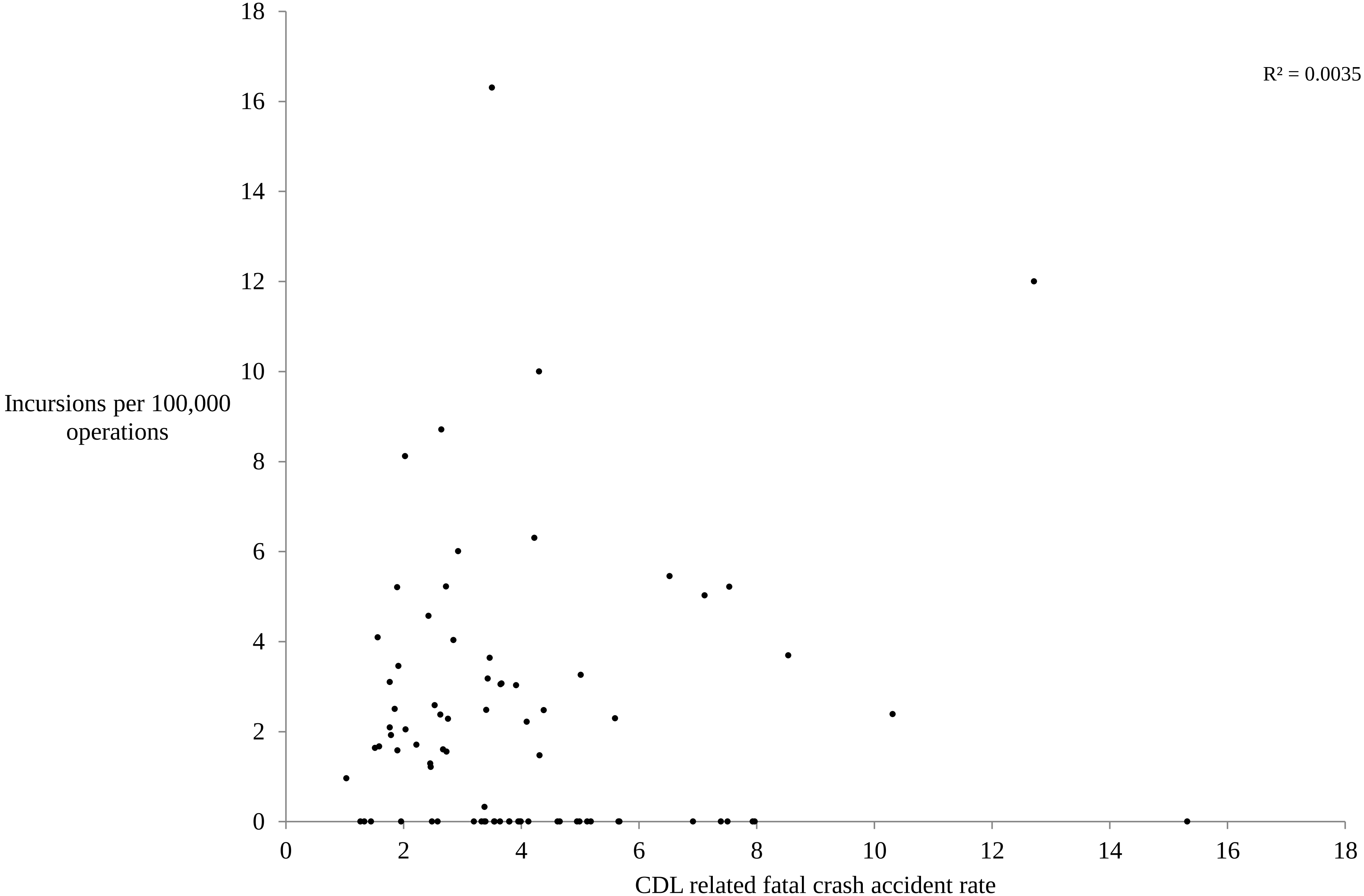

Figure 13: CDL related fatal accident rate vs. historical incursion rate – Great Lakes Region

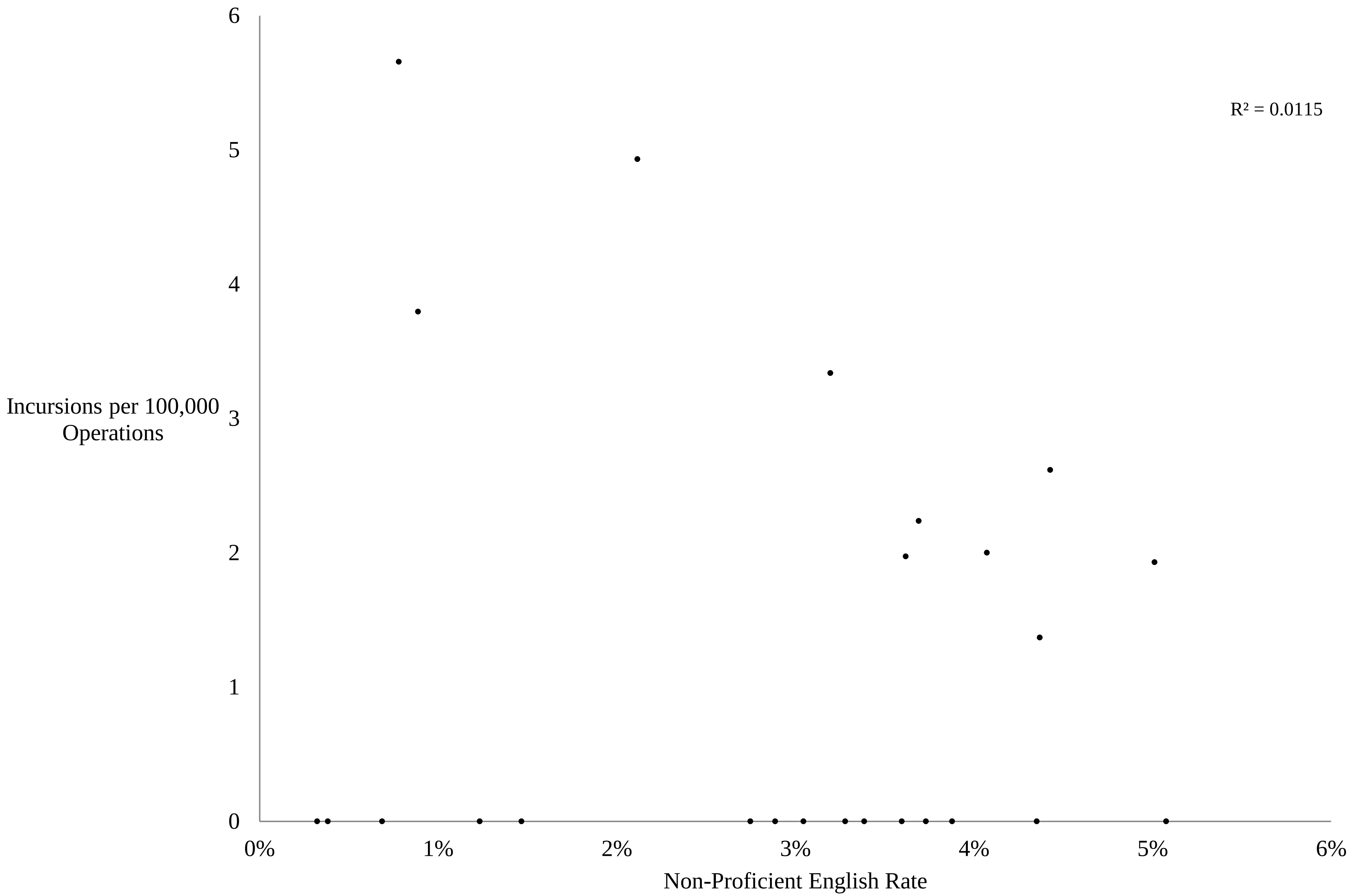

Figure 14: English proficiency rate vs. historical incursion rate – New England Region

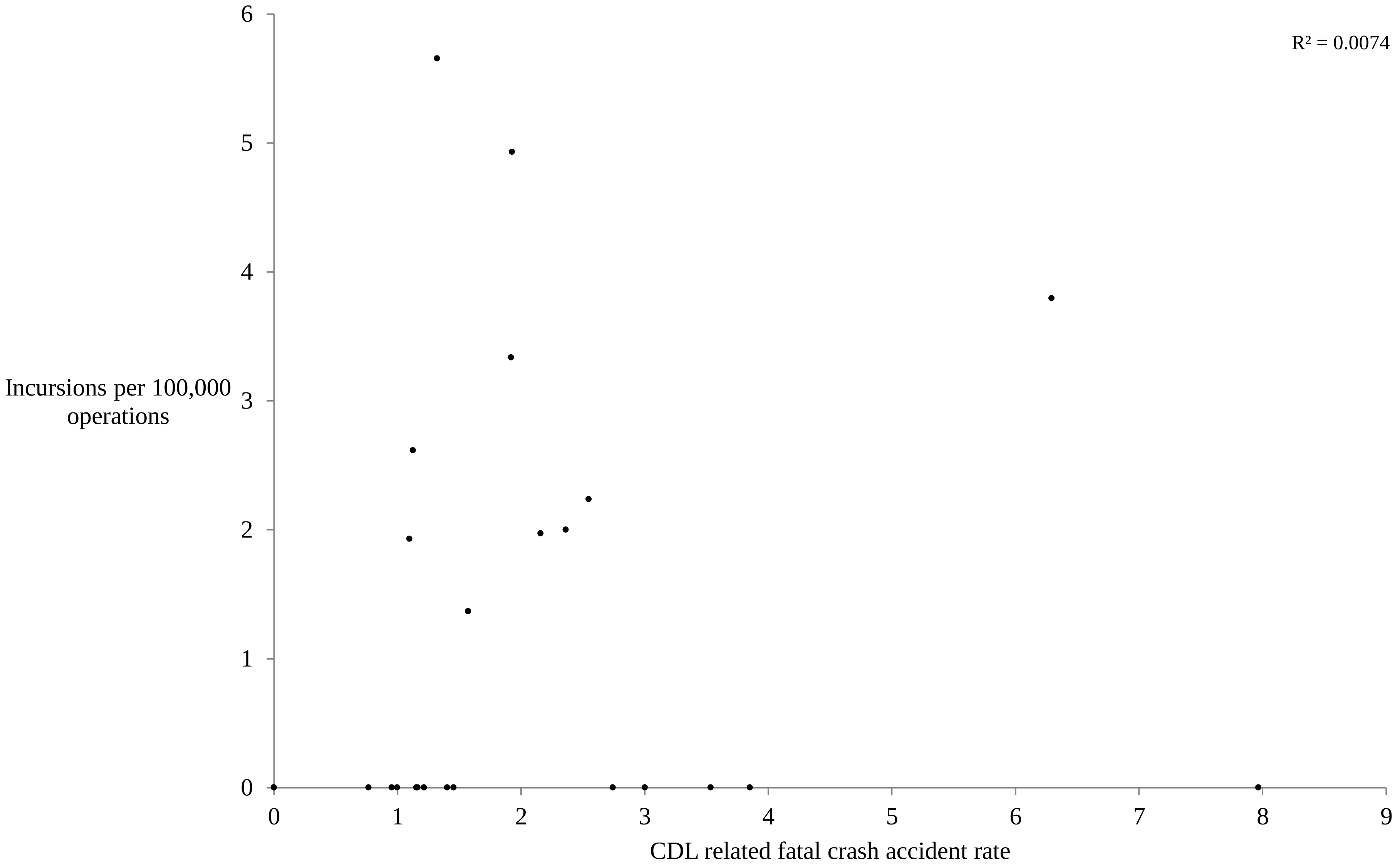

Figure 15: CDL related fatal accident rate vs. historical incursion rate – New England Region

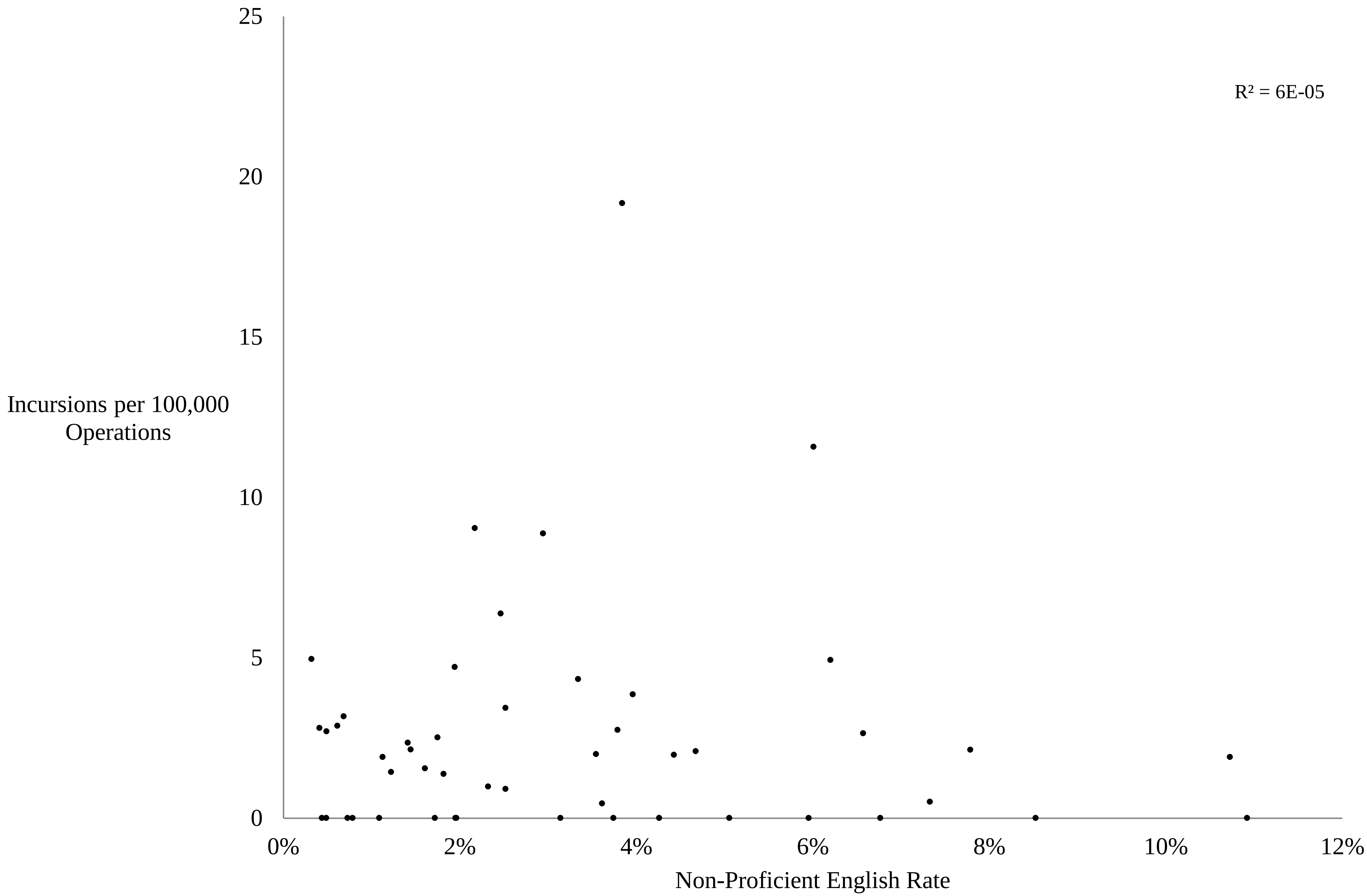

Figure 16: English proficiency rate vs. historical incursion rate – Northwest Mountain Region

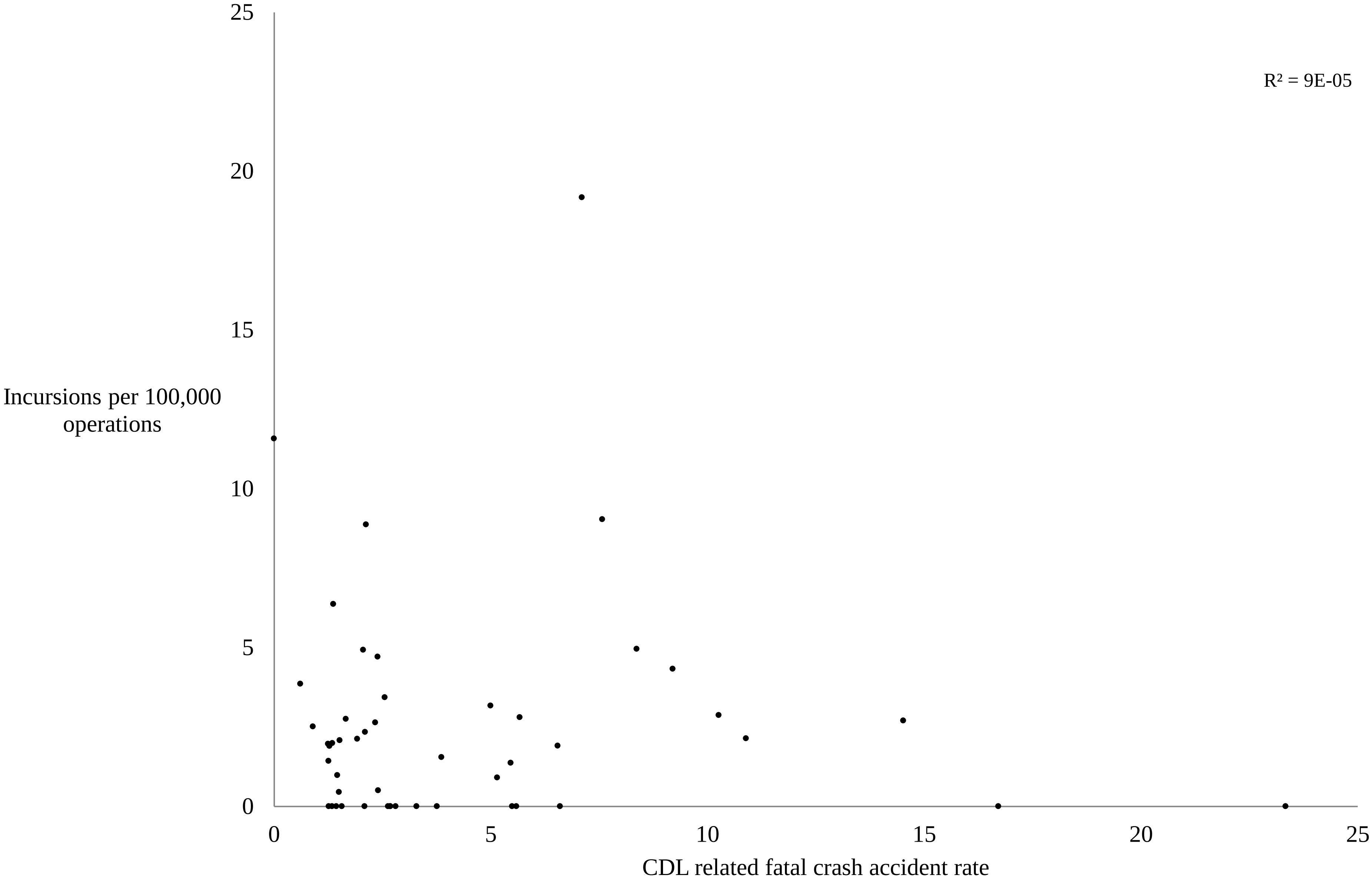

Figure 17: CDL related fatal accident rate vs. historical incursion rate – Northwest Mountain Region

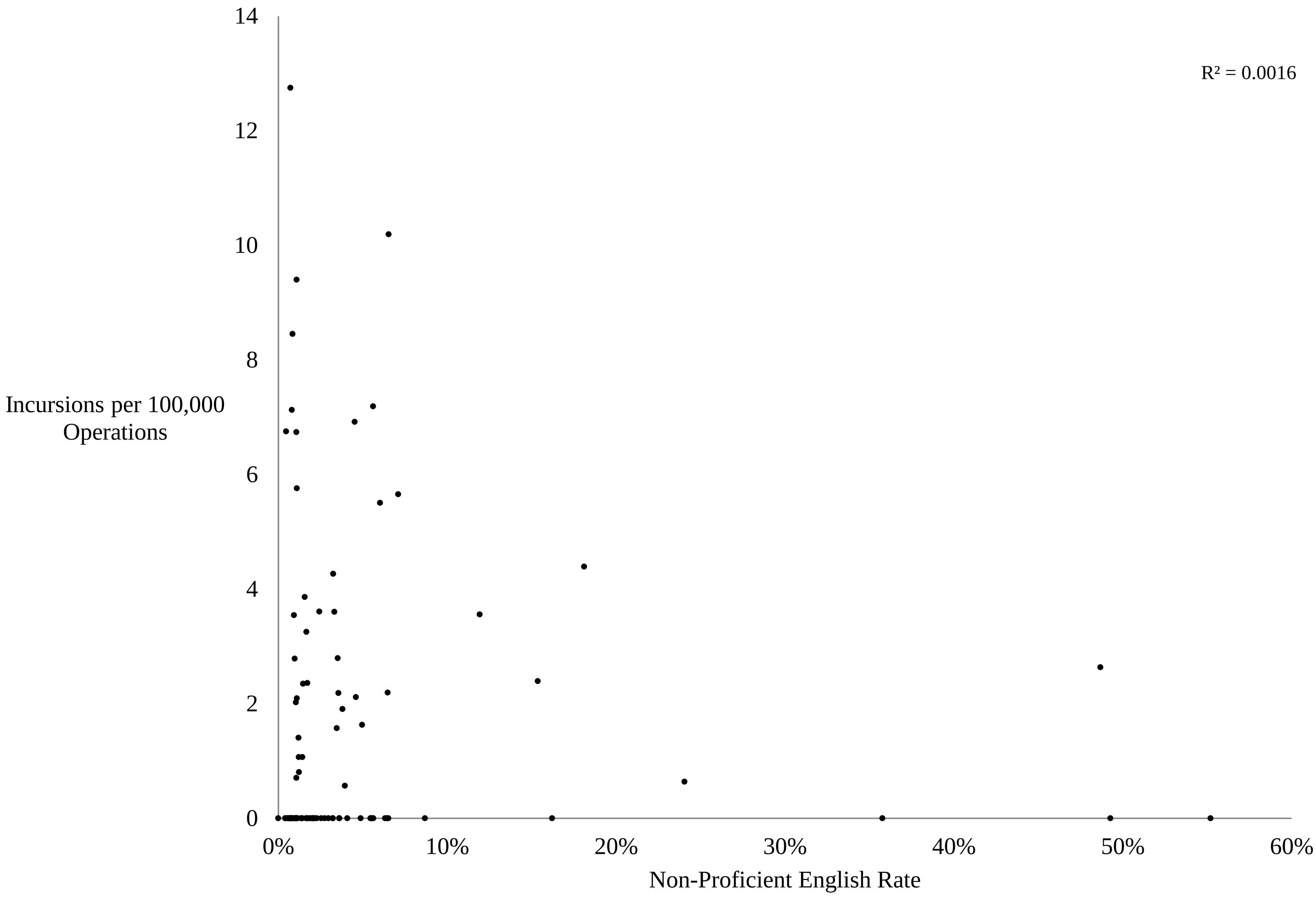

Figure 18: English proficiency rate vs. historical incursion rate – Southern Region

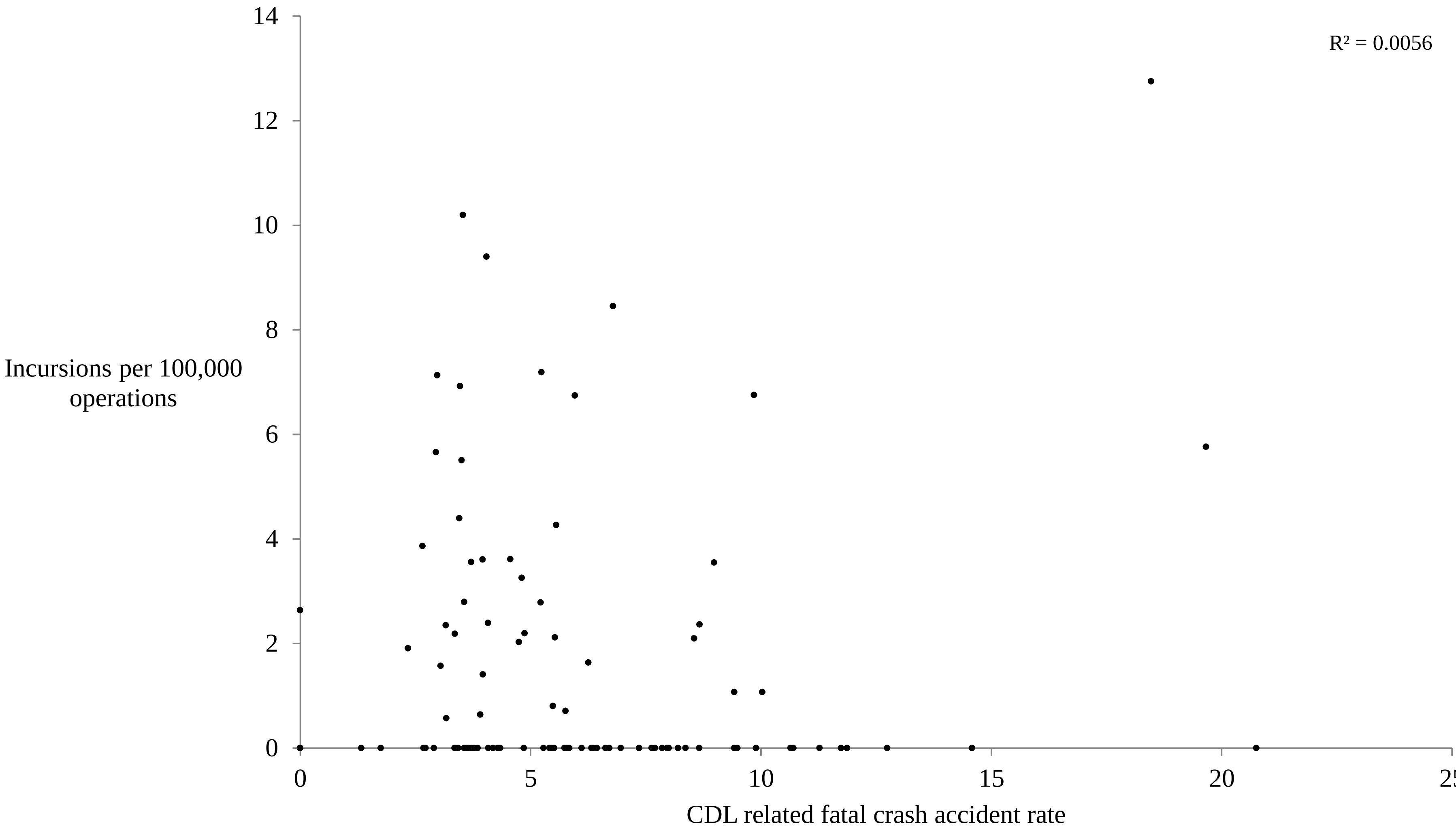

Figure 19: CDL related fatal accident rate vs. historical incursion rate – Southern Region

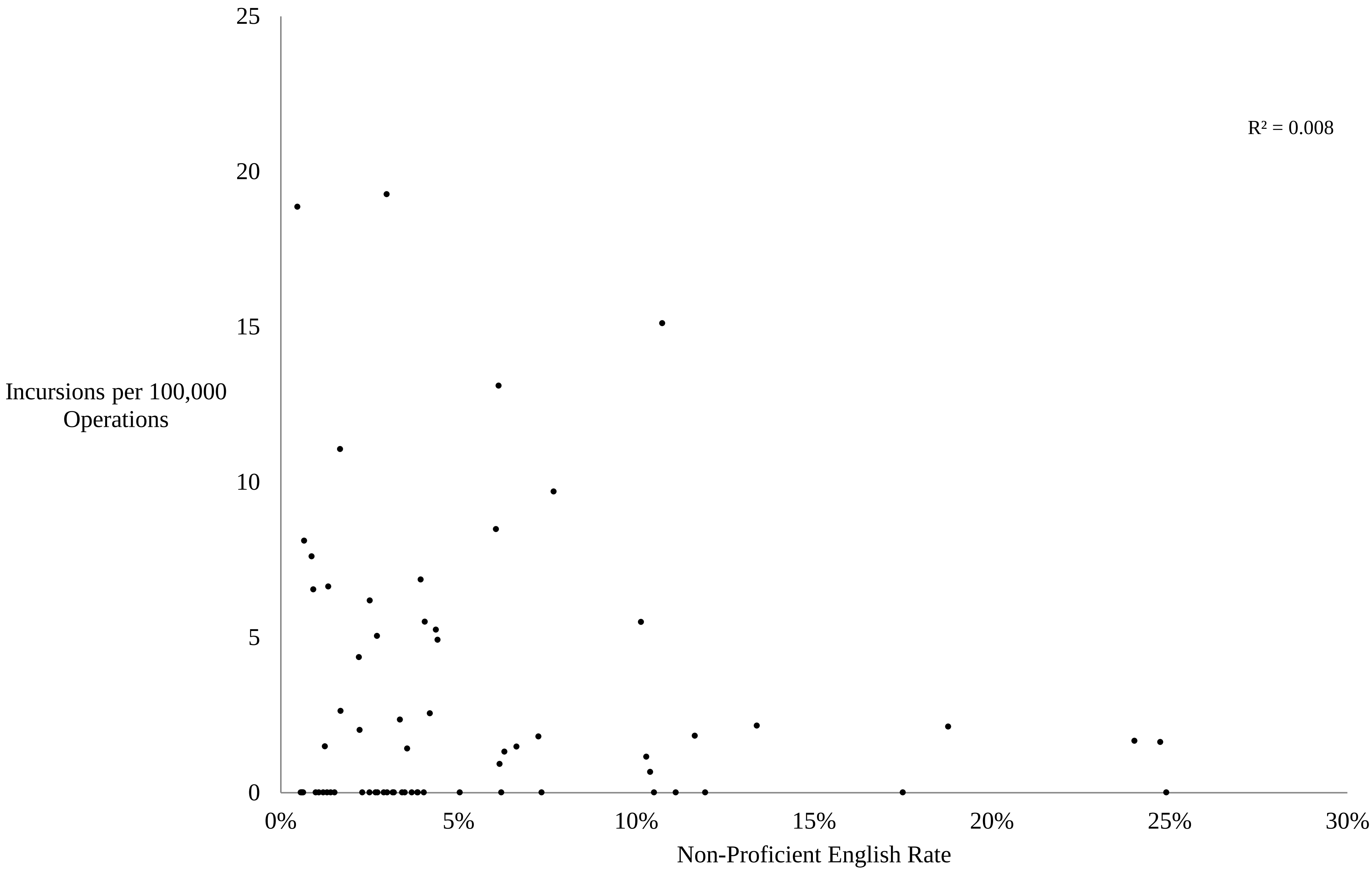

Figure 20: English proficiency rate vs. historical incursion rate – Southwest Region

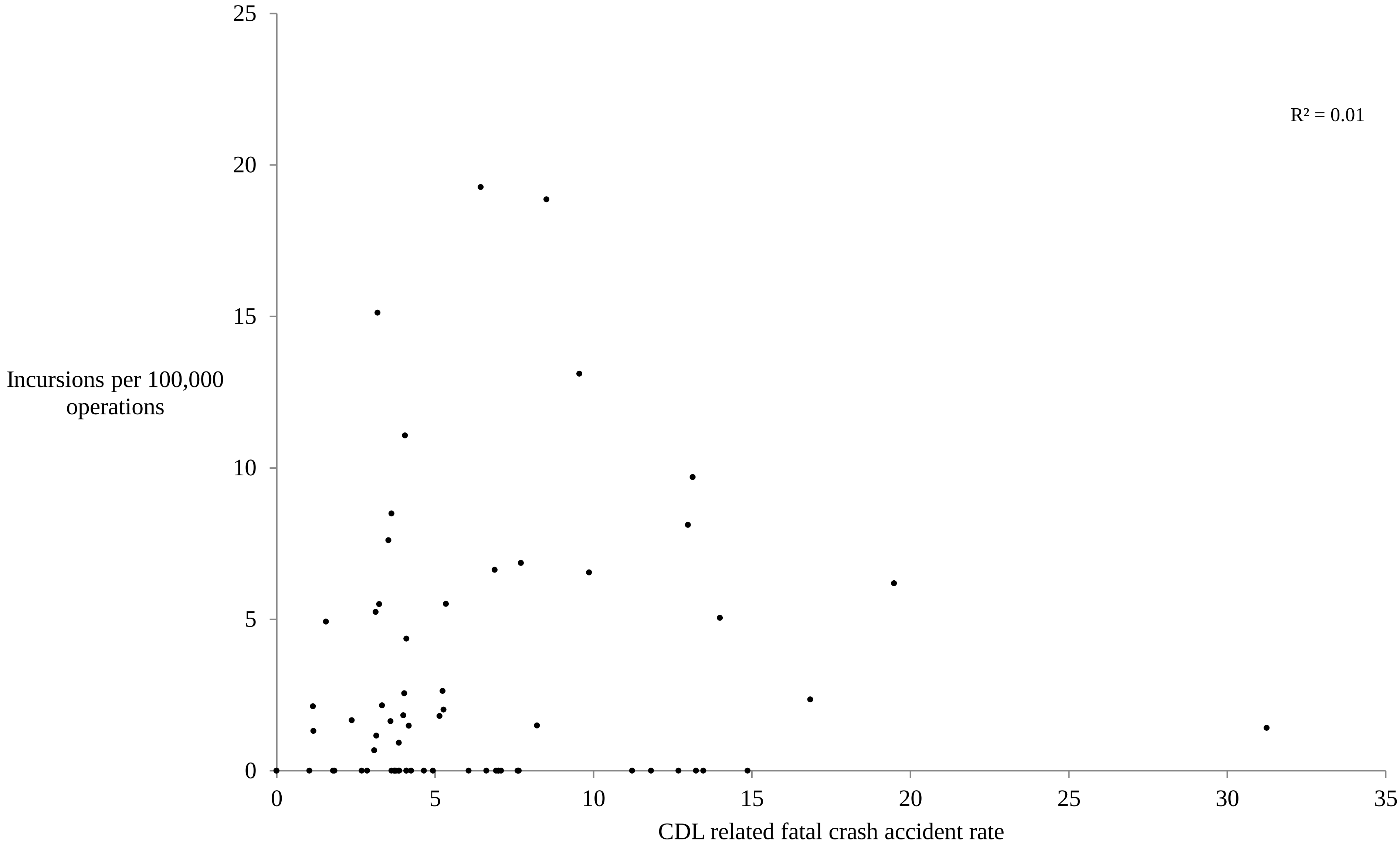

Figure 21: CDL related fatal accident rate vs. historical incursion rate – Southwest Region

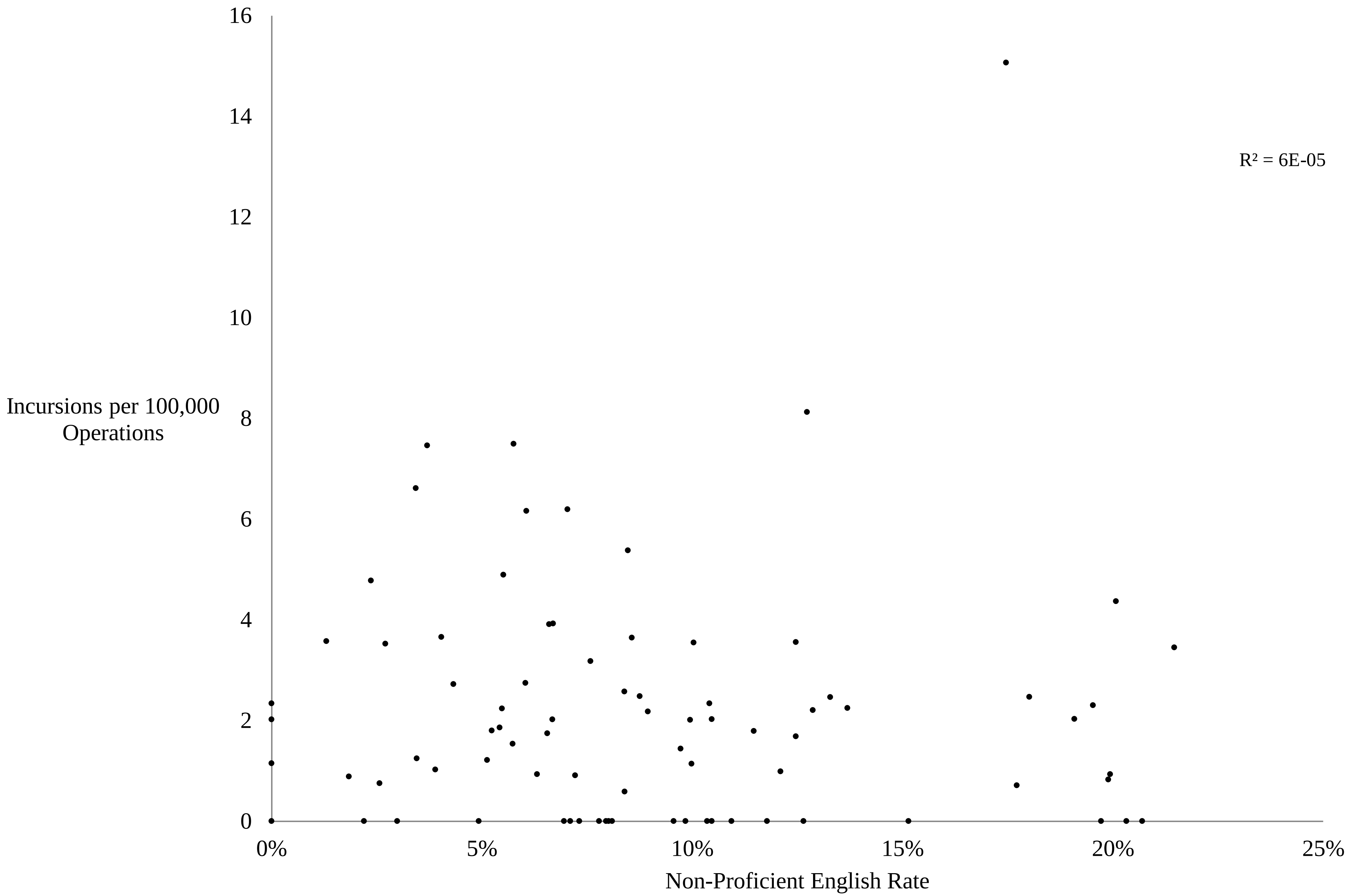

Figure 22: English proficiency rate vs. historical incursion rate – Western Pacific Region

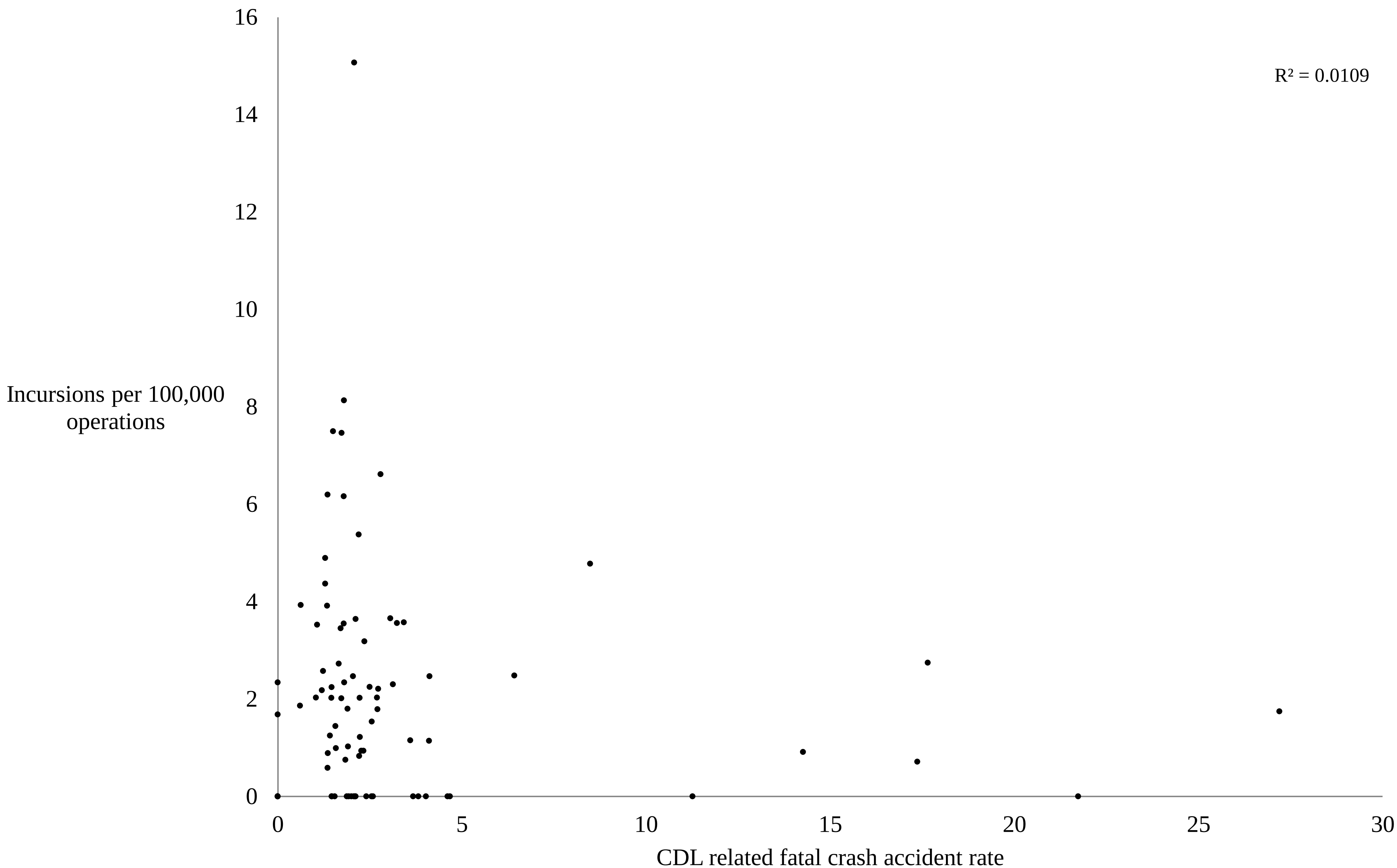

Figure 23: CDL related fatal accident rate vs. historical incursion rate – Western Pacific Region

4.4 Rank-ordered prioritization framework

While RSATs are an effective tool for improving runway safety and identifying methods for improved risk management, resource limitations prevent them from visiting all of the airports recognized by the FAA. It is this limitation that prompted the development of a framework for prioritization developed by Rogerson and Lambert in 2012. This tool, currently in use by the FAA, will benefit greatly from the inclusion of human and cultural factors.

The rank-ordered prioritization method described below will take into account an exposure to risk based on relative high levels in the seven previously described factor categories for each airport. This method is designed to work within the context of an FAA region.

For each factor, airports are ranked from highest to lowest level, and those airports falling in the top twenty ranking receive one point. The sum of points across the factors constitutes the aggregate score. Therefore, prior to the inclusion of the human and cultural factors, the highest aggregate score for an airport is five. The inclusion of the human and cultural factors increases the highest possible aggregate score to seven.

The top ten prioritized airports for each FAA Region, as determined through this rank-ordered method, are shown below. Two sets of rankings, both excluding and including the human and cultural factors are presented so that the effect of the factors can be seen. It is important to note those airports which, prior to the inclusion of human factors, were not identified as highly prioritized airports. These airports are represented by bold lettering in the prioritization for the FAA regions.

With the addition of the human factors class, the prioritization framework is expanded to include the factors shown in Table 5.

A review of the regional results is offered to highlight the effect of the human and cultural factors in terms of addition and removal of airports to the prioritization. Tables 6 - 23 provide the top ten airports for each FAA Region using the rank-ordered prioritization method.

Alaska Region

Due to the size of the Alaska region the effect of the human and cultural factors cannot be seen through the rank-ordered prioritization. However, the effects will be visible when the ratio based prioritization method is introduced in later sections.

Central Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to five airports that were not identified in the initial approach. Of particular interest are Spirit of St. Louis, Kansas City International and Eppley Airfield. The airports have yearly combined operations of over 300,000 and recorded five incursions in FY 2011. Two major international airports, Lambert-St. Louis and Des Moines, are shifted to the top of the prioritization ranking after the inclusion of the human and cultural factors. Several municipal airports also fall from the top of the prioritization.

Eastern Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to four airports that were not identified in the initial approach. Of particular interest are Teterboro and Atlantic City International Airport. The airports have combined yearly operations of over 250,000 and recorded twelve incursions in FY 2011.

Great Lakes

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to three airports that were not identified in the initial approach. St. Paul Down Town, Lafayette and Flying Cloud have yearly combined operations of over 300,000 and recorded twelve incursions in FY 2011. Major airports including O'Hare, Detroit Metro and Midway remain highly prioritized.

New England

The effect of the human and cultural factors can be seen through the restructuring of the prioritization in this region. Due to the size of the region there are no airports added to the prioritization. However, the removal of airports, including Portland International Jetport, can bring greater attention to those with potentially higher risk.

Northwest Mountain

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to four airports that were not identified in the initial approach. Yakima Air Terminal/Mcallister Field, Friedman Memorial, Grant CO International, and Walla Walla Regional have combined yearly operations of nearly 200,000 and recorded nine incursions in FY 2011.

Southern Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports. The removal of airports, including Flagler CO, Daytona Beach International and Louisville International, can bring greater attention to those with potentially higher risk.

Southwest Region

The effect of the human and cultural factors can be seen through the restructuring of the prioritization in this region. Although there are not airports added to the prioritization, the removal of airports, including Corpus Christi International, San Angelo Regional/Mathis Field and Baton Rouge Metro, can bring greater attention to those with potentially higher risk.

Western Pacific Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to four airports that were not identified in the initial approach. Of particular interest are Van Nuys, Los Angeles International. The airports have combined yearly operations of nearly 1,000,000 and recorded twenty four incursions in FY 2011.

Table 5. Factors used for the prioritization of airports to receive airport safety audits- including human and cultural factors

Factor	*Description*
Runway Geometry	Sum of closely aligned runways, crossing runways, multiple crossing runways, parallel runways, short taxi routes, bullseye formation
Airport Features	Sum of need for 139 Airport certification, presence of a flight school, status as federal contract tower
Runway Incursions	Total number of runway incursions (per year)
Runway Incursions per 100,000 Operations	Runway incursion rate (per year)
Airport Operations	Total operations (per year)
English proficiency level	Rate of non-proficient English speakers in surrounding population
Ground vehicle operations	Rate of CDL related fatal accidents in surrounding population

Table 6. Top prioritized airports Alaska Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Merrill Field	MRI	5
2	Juneau International	JNU	5
3	Fairbanks	FAI	5
4	Kenai Municipal	ENA	5
5	Bethel	BET	5
6	Ted Stevens Anchorage International	ANC	5
7	King Salmom	AKN	5
8	Kodiak	ADQ	5

Rankings do not include human factors class

Table 7. Top prioritized airports Alaska Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Merrill Field	MRI	8
2	Juneau International	JNU	8
3	Fairbanks	FAI	8
4	Kenai Municipal	ENA	8
5	Bethel	BET	8
6	Ted Stevens Anchorage International	ANC	8
7	King Salmom	AKN	8
8	Kodiak	ADQ	8

Rankings include human factors class

Table 8. Top prioritized airports Central Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Philip Billard Municipal	TOP	5
2	Lambert-St Louis International	STL	5
3	Rosecrans Memorial	STJ	5
4	Salina Municipal	SLN	5
5	Springfield-Branson Regional	SGF	5
6	Johnson CO Exec	OJC	5
7	Lincoln Municipal	LNK	5
8	Joplin Regional	JLN	5
9	Hutchinson Municipal	HUT	5
10	Des Moines International	DSM	5

Rankings do not include human factors class

Table 9. Top prioritized airports Central Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Lambert-St Louis International	STL	7
2	Lincoln Municipal	LNK	7
3	Joplin Regional	JLN	7
4	Des Moines International	DSM	7
5	Philip Billard Municipal	TOP	6
6	**Sioux Gateway/Col Bud Day Field**	**SUX**	**6**
7	**Spirit of St Louis**	**SUS**	**6**
8	Rosecrans Memorial	STJ	6
9	Salina Municipal	SLN	6
10	Springfield-Branson Regional	SGF	6
11	**Eppley Airfield**	**OMA**	**6**
12	Johnson CO Exec	OJC	6
13	**Manhattan Regional**	**MHK**	**6**
14	**Kansas City International**	**MCI**	**6**
15	Hutchinson Municipal	HUT	6

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 10. Top prioritized airports Eastern Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Richmond International	RIC	5
2	Pittsburgh International	PIT	5
3	Philadelphia International	PHL	5
4	Newport News/Williamsburg International	PHF	5
5	Long Island MacArthur	ISP	5
6	Ronald Reagan Washington National	DCA	5
7	John F Kennedy International	JFK	4
8	Westchester CO	HPN	4
9	Newark International	EWR	4
10	Baltimore-Washington International	BWI	4

Rankings do not include human and cultural factors

Table 11. Top prioritized airports Eastern Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Long Island MacArthur	ISP	7
2	Philadelphia International	PHL	6
3	Ronald Reagan National	DCA	6
4	Richmond International	RIC	5
5	Pittsburgh International	PIT	5
6	Newport News/Williamsburg International	PHF	5
7	John F Kennedy International	JFK	5
8	Westchester CO	HPN	5
9	Newark International	EWR	5
10	**Teterboro**	**TEB**	**4**
11	**Reading Regional/Carl A Spaatz Field**	**RDG**	**4**
12	**Morristown Municipal**	**MMU**	**4**
13	Baltimore-Washington Intl	BWI	4
14	**Atlantic City International**	**ACY**	**4**

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 12. Top prioritized airports Great Lakes Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Madison	MSN	5
2	Milwaukee	MKE	5
3	Willow Run	YIP	4
4	Palwaukee	PWK	4
5	O'Hare	ORD	4
6	Minneapolis	MSP	4
7	Crystal	MIC	4
8	Midway	MDW	4
9	Cin-Lunken	LUK	4
10	Detroit Metro	DTW	4

Rankings do not include human factors class

Table 13. Top prioritized airports Great Lakes Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Madison	MSN	6
2	Milwaukee	MKE	6
3	Palwaukee	PWK	5
4	O'Hare	ORD	5
5	Minneapolis	MSP	5
6	Crystal	MIC	5
7	Midway	MDW	5
8	Detroit Metro	DTW	5
9	Willow Run	YIP	4
10	**St. Paul Down Town**	**STP**	**4**
11	Cin-Lunken	LUK	4
12	**Lafayette**	**LAF**	**4**
13	**Flying Cloud**	**FCM**	**4**

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 14. Top prioritized airports New England Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Portland International Jetport	PWM	5
2	Theodore Francis Green State	PVD	5
3	Norwood Memorial	OWD	5
4	Manchester	MHT	5
5	Lawrence Municipal	LWM	5
6	Barnstable Municipal	HYA	5
7	Hartford-Brainard	HFD	5
8	Danbury Municipal	DXR	5
9	Burlington International	BTV	5
10	Logan International	BOS	5
11	Hanscomb Field	BED	5
12	Bradley	BDL	5

Rankings do not include human and cultural factors

Table 15. Top prioritized airports New England – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Theodore Francis Green State	PVD	7
2	Norwood Memorial	OWD	7
3	Manchester	MHT	7
4	Lawrence Municipal	LWM	7
5	Barnstable Municipal	HYA	7
6	Hartford-Brainard	HFD	7
7	Danbury Municipal	DXR	7
8	Logan International	BOS	7
9	Hanscomb Field	BED	7
10	Bradley	BDL	7

Rankings include human factors class

Table 16. Top prioritized airports Northwest Mountain Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Provo Municipal	PVU	5
2	Snohomish CO Paine	PAE	5
3	Ogden-Hinckley	OGD	5
4	Billings Logan International	BIL	5
5	Pueblo Memorial	PUB	4
6	Portland International	PDX	4
7	Helena Regional	HLN	4
8	JEFFCO	BJC	4
9	Centennial	APA	4
10	Salt Lake City International	SLC	3
11	Seattle-Tacoma International	SEA	3
12	Eastern Oregon Regional	PDT	3
13	Olympia	OLM	3
14	Mahlon Sweet Field	EUG	3
15	Natrona CO International	CPR	3
16	Gallatin Field	BZN	3

Rankings do not include human and cultural factors

Table 17. Top prioritized airports Northwest Mountain Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Billings Logan International	BIL	6
2	Provo Municipal	PVU	5
3	Pueblo Memorial	PUB	5
4	Portland International	PDX	5
5	Snohomish CO Paine	PAE	5
6	Ogden-Hinckley	OGD	5
7	Helena Regional	HLN	5
8	JEFFCO	BJC	5
9	Centennial	APA	5
10	**Yakima Air Terminal/Mcallister Field**	**YKM**	**4**
11	**Friedman Memorial**	**SUN**	**4**
12	Salt Lake City International	SLC	4
13	Seattle-Tacoma International	SEA	4
14	Eastern Oregon Regional	PDT	4
15	**Grant CO International**	**MWH**	**4**
16	Mahlon Sweet Field	EUG	4
17	Natrona CO International	CPR	4
18	Gallatin Field	BZN	4
19	**Walla Walla Regional**	**ALW**	**4**

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 18. Top prioritized airports Southern Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Dekalb-Peachtree	PDK	5
2	Miami International	MIA	5
3	Ft Lauderdale/Hollywood International	FLL	5
4	Cincinnati/Northern Kentucky International	CVG	5
5	Charlotte/Douglas International	CLT	5
6	Vero Beach Municipal	VRB	4
7	Tampa International	TPA	4
8	Orlando Sanford	SFB	4
9	Flagler CO	XFL	3
10	Luis Munoz Marin International	SJU	3
11	Louisville International-Standiford Field	SDF	3
12	Ft. Lauderdale Executive	FXE	3
13	Daytona Beach International	DAB	3

Rankings do not include human and cultural factors

Table 19. Top prioritized airports Southern Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Dekalb-Peachtree Airport	PDK	6
2	Miami International	MIA	6
3	Ft Lauderdale/Hollywood International	FLL	6
4	Cincinnati/Northern Kentucky International	CVG	5
5	Charlotte/Douglas International	CLT	5
6	Vero Beach Municipal	VRB	4
7	Tampa International	TPA	4
8	Luis Munoz Marin International	SJU	4
9	Orlando Sanford	SFB	4
10	Ft. Lauderdale Executive	FXE	4

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 20. Top prioritized airports Southwest Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Tulsa International	TUL	5
2	Dallas Love Field	DAL	5
3	Albuquerque International	ABQ	5
4	San Antonio International	SAT	4
5	Monroe Regional	MLU	4
6	Midland International	MAF	4
7	Lafayette Regional	LFT	4
8	William P. Hobby	HOU	4
9	Baton Rouge Metro	BTR	4
10	San Angelo Regional/Mathis Field	SJT	3
11	Lea County Regional	HOB	3
12	Corpus Christi International	CRP	3

Rankings do not include human and cultural factors

Table 21. Top prioritized airports Southwest Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Dallas Love Field	DAL	6
2	Tulsa International	TUL	5
3	Monroe Regional	MLU	5
4	Midland International	MAF	5
5	William P. Hobby	HOU	5
6	Lea County Regional	HOB	5
7	Baton Rouge Metro	BTR	5
8	Albuquerque International	ABQ	5
9	San Antonio International	SAT	4
10	Lafayette Regional	LFT	4

Rankings include human and cultural factors

Table 22. Top prioritized airports Western Pacific Region – Rank-ordered prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	John Wayne	SNA	5
2	Honolulu International	HNL	5
3	San Francisco International	SFO	4
4	Ernest A Love Field	PRC	4
5	Chino	CNO	4
6	North Las Vegas	VGT	3
7	Tucson International	TUS	3
8	Sonoma CO	STS	3
9	Gillespie Field	SEE	3
10	Ryan Field	RYN	3
11	Reno/Tahoe International	RNO	3
12	Montgomery Field	MYF	3
13	Long Beach/Daugherty Field	LGB	3
14	McCarran International	LAS	3
15	Williams Gateway	IWA	3
16	Phoenix Deer Valley	DVT	3

Rankings do not include human and cultural factors

Table 23. Top prioritized airports Western Pacific Region – Rank-ordered prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	John Wayne	SNA	6
2	Honolulu International	HNL	5
3	Chino	CNO	5
4	**Van Nuys**	**VNY**	**4**
5	San Francisco International	SFO	4
6	Ernest A Love Field	PRC	4
7	Long Beach/Daugherty Field	LGB	4
8	**Whiteman**	**WHP**	**3**
9	North Las Vegas	VGT	3
10	Tucson International	TUS	3
11	Sonoma CO	STS	3
12	Gillespie Field	SEE	3
13	Ryan Field	RYN	3
14	Reno/Tahoe International	RNO	3
15	**Redding Municipal**	**RDD**	**3**
16	**Palm Springs International**	**PSP**	**3**
17	**Brackett Field**	**POC**	**3**
18	Montgomery Field	MYF	3
19	**Monterey Peninsula**	**MRY**	**3**
20	**Los Angeles International**	**LAX**	**3**
21	McCarran International	LAS	3
22	Williams Gateway	IWA	3
23	Phoenix Deer Valley	DVT	3

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

4.5 Alternative method: ratio based prioritization

The rank-ordered prioritization method used to generate the previous rankings, initially implemented for its ease of use and relative straightforward nature, can lead to misleading conclusions due to the combination of ordinal and ratio scales. For example, simply assigning a rank to the airports in terms of its operations level does not account for significant differences that might exist in terms of its operations. The same issue is present when ranking the airports in the other factors.

A more accurate prioritization method would remove this combination and create a ranking based on purely a ratio scale. Rather than determining an aggregate score based on the sum of the times an airport appears in the top rankings for each factor, the following scoring method will determine an aggregate score based on the relative performance of an airport in each of the factors. The equation below shows the aggregate score calculation for an airport *i* within an FAA region. $Factor_{i,j}$ refers to the performance of airport *i* in factor *j*, while $Factor_{max,j}$ refers to the airport with the highest performance in factor *j*.

$$Score_i = \sum_{j=1}^{7} \frac{Factor_{i,j}}{Factor_{Max,j}}$$

Equation 1: Aggregate score calculation

The top ten prioritized airports for each FAA Region, as determined through this ratio based method, are in Tables 24 - 41. Two sets of rankings, both excluding and including the human and cultural factors are presented so that the effect of the factors can be seen. It is important to note those airports which, prior to the inclusion of human factors, were not identified as highly prioritized airports. These airports are represented by bold lettering in the prioritization for the FAA regions.

Alaska Region

The effect of the human and cultural factors can be seen through the restructuring of the prioritization in this region. Of particular interest are Kodiak, Kenai Municipal, Fairbanks, and Bethel. These airports all experience a change in ranking due to the newly incorporated factors.

Central Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to two airports that were not identified in the initial approach. Garden City Regional and Sioux Gateway/Col Bud Day Field have a combined incursion rate of nearly seven incursions per 100,000 operations.

Eastern Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to Westchester CO Airport. This airport, not identified in the initial approach, has nearly 200,000 yearly operations and recorded four incursions in FY 2011.

Great Lakes

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to Palwaukee and Madison Airports. These airports, not identified in the initial approach, have over 150,000 combined yearly operations and recorded ten incursions in Fiscal Year 2011.

New England

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to Theodore Francis Green State and New Bedford Regional. These airports, not identified in the initial approach, have over 150,000 combined yearly operations and recorded two incursions in FY 2011.

Northwest Mountain

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to five airports not previously identified. Of particular interest are JEFFCO, Billings Logan International and Portland International, which have nearly 400,000 combined yearly operations and recorded ten incursions in FY 2011.

Southern Region

The addition of the human factors class has a significant effect as it restructures the ranking of the top ten prioritized airports.

Southwest Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to Laredo International, Lea County Regional and Monroe Regional. These airports have over 100,000 combined yearly operations and recorded eight incursions in FY 2011.

Western Pacific Region

The addition of the human factors class has a significant effect as it not only restructures the ranking of the top ten prioritized airports, but also helps bring attention to Van Nuys and Monterey Peninsula Airports. These airports have nearly 350,000 combined yearly operations and recorded nine incursions in FY 2011.

Table 24. Top prioritized airports Alaskan Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Merrill Field	MRI	4.00
2	Fairbanks	FAI	2.90
3	Kodiak	ADQ	2.44
4	Bethel	BET	2.35
5	Kenai Municipal	ENA	2.15
6	Ted Stevens Anchorage International	ANC	1.55
7	Juneau International	JNU	1.52
8	King Salmon	AKN	1.35

Rankings do not include human and cultural factors

Table 25. Top prioritized airports Alaskan Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Merrill Field	MRI	4.97
2	Kodiak	ADQ	3.44
3	Kenai Municipal	ENA	3.28
4	Fairbanks	FAI	3.23
5	Bethel	BET	3.07
6	Ted Stevens Anchorage International	ANC	2.48
7	Juneau International	JNU	1.66
8	King Salmom	AKN	1.49

Rankings include human and cultural factors

Table 26. Top prioritized airports Central – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Joplin Regional	JLN	3.23
2	Lincoln Municipal	LNK	2.84
3	**Waterloo Municipal**	**ALO**	**2.58**
4	**Kansas City International**	**MCI**	**2.34**
5	Lambert-St Louis International	STL	2.34
6	Des Moines International	DSM	2.06
7	**Central Nebraska Regional**	**GRI**	**1.90**
8	Johnson CO Exec	OJC	1.83
9	**Branson**	**BBG**	**1.77**
10	**Wichita Mid-Continent**	**ICT**	**1.75**

Rankings do not include human and cultural factors
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 27. Top prioritized airports Central Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Joplin Regional	JLN	4.32
2	**Garden City Regional**	**GCK**	**3.09**
3	Lincoln Municipal	LNK	3.06
4	Waterloo Municipal	ALO	2.79
5	Central Nebraska Regional	GRI	2.78
6	Kansas City International	MCI	2.65
7	Lambert-St Louis International	STL	2.57
8	Des Moines International	DSM	2.37
9	**Sioux Gateway/Col Bud Day Field**	**SUX**	**2.11**
10	Branson	BBG	2.07

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 28. Top prioritized airports Eastern Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Philadelphia International	PHL	4.61
2	Newark International	EWR	4.51
3	Pittsburgh International	PIT	3.96
4	Ronald Reagan Washington National	DCA	3.38
5	**Teterboro**	**TEB**	**3.26**
6	Long Island MacArthur	ISP	3.13
7	John F Kennedy International	JFK	3.13
8	**Norfolk International**	**ORF**	**2.92**
90	Baltimore-Washington International	BWI	2.94
10	**Niagara Falls International**	**IAG**	**2.83**

Rankings do not include human and cultural factors
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 29. Top prioritized airports Eastern Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Newark International	EWR	5.48
2	Philadelphia International	PHL	4.81
3	Teterboro	TEB	4.24
4	John F Kennedy International	JFK	4.07
5	Pittsburgh International	PIT	4.01
6	Ronald Reagan Washington National	DCA	3.83
7	Long Island MacArthur	ISP	3.45
8	**Westchester CO**	**HPN**	**3.25**
9	Baltimore-Washington International	BWI	3.10
10	Norfolk International	ORF	3.02

Rankings include human and cultural factors
Bold lettering addition of airport due to human and cultural factors

Table 30. Top prioritized airports Great Lakes Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	O'Hare	ORD	3.95
2	Crystal	MIC	3.15
3	Minneapolis	MSP	3.11
4	Milwaukee	MKE	2.66
5	Detroit Metro	DTW	2.49
6	Midway	MDW	2.40
7	Willow Run	YIP	2.36
8	Cin-Lunken	LUK	2.35
9	**Oshkosh**	**OSH**	**2.22**
10	**Flying Cloud**	**FCM**	**2.08**

Rankings do not include human and cultural factors
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 31. Top prioritized airports Great Lakes Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	O'Hare	ORD	5.06
2	Crystal	MIC	3.69
3	Minneapolis	MSP	3.68
4	Midway	MDW	3.45
5	Milwaukee	MKE	3.10
6	**Palwaukee**	**PWK**	**2.97**
7	Detroit Metro	DTW	2.91
8	**Madison**	**MSN**	**2.70**
9	Flying Cloud	FCM	2.68
10	Willow Run	YIP	2.66

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 32. Top prioritized airports New England Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Logan International	BOS	4.56
2	Burlington International	BTV	2.33
3	**Portland International Jetport**	**PWM**	**2.09**
4	Bradley	BDL	1.90
5	Hartford-Brainard	HFD	1.86
6	Hanscomb Field	BED	1.83
7	Manchester	MHT	1.78
8	**Waterbury-Oxford**	**OXC**	**1.26**
9	Barnstable Municipal	HYA	1.16
10	**Nantucket Memorial**	**ACK**	**1.09**

Rankings do not include human and cultural factors
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 33. Top prioritized airports New England Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Logan International	BOS	5.58
2	Portland International Jetport	PWM	3.06
3	Bradley	BDL	3.00
4	Hanscomb Field	BED	2.95
5	Hartford-Brainard	HFD	2.73
6	Burlington International	BTV	2.65
7	Manchester	MHT	2.44
8	Waterbury-Oxford	OXC	2.31
9	**Theodore Francis Green State**	**PVD**	**2.07**
10	**New Bedford Regional**	**EWB**	**2.03**

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 34. Top prioritized airports Northwest Mountain Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Eastern Oregon Regional	PDT	2.34
2	Salt Lake City International	SLC	2.32
3	Centennial	APA	2.14
4	Ogden-Hinckley	OGD	2.10
5	**Southwest Oregon Regional**	**OTH**	**2.04**
6	**Denver International**	**DEN**	**1.95**
7	**Sardy Field**	**ASE**	**1.89**
8	Snohomish CO Paine	PAE	1.85
9	Seattle-Tacoma International	SEA	1.74
10	**Helena Regional**	**HLN**	**1.74**

Rankings do not include human factors class
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 35. Top prioritized airports Northwest Mountain Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Eastern Oregon Regional	PDT	2.87
2	Centennial Airport	APA	2.80
3	Denver International	DEN	2.73
3	Salt Lake City International	SLC	2.71
4	**Grant CO International**	**MWH**	**2.49**
5	Sardy Field	ASE	2.45
6	**Tri-Cities**	**PSC**	**2.43**
7	**JEFFCO**	**BJC**	**2.39**
8	**Billings Logan International**	**BIL**	**2.39**
9	Ogden-Hinckley	OGD	2.39
10	Southwest Oregon Regional	OTH	2.17
10	Seattle-Tacoma International	SEA	2.17
10	**Portland International**	**PDX**	**2.17**

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 36. Top prioritized airports Southern Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Charlotte/Douglas International	CLT	3.65
2	**St-Petersburg-Clearwater International**	**PIE**	**2.14**
3	Miami International	MIA	2.03
4	**Atlanta Hartsfield International**	**ATL**	**1.89**
5	Ft Lauderdale/Hollywood International	FLL	1.84
6	**St Augustine**	**SGJ**	**1.66**
7	Dekalb-Peachtree	PDK	1.65
8	**North Perry**	**HWO**	**1.61**
9	Flagler CO	XFL	1.60
10	**Valdosta Regional**	**VLD**	**1.57**

Rankings do not include human and cultural factors
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 37. Top prioritized airports Southern Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Charlotte/Douglas International	CLT	3.88
2	Miami International	MIA	2.53
3	St-Petersburg-Clearwater International	PIE	2.33
4	Atlanta Hartsfield International	ATL	2.29
5	Ft Lauderdale/Hollywood International	FLL	2.24
6	Valdosta Regional	VLD	2.11
7	North Perry	HWO	2.09
8	Dekalb-Peachtree	PDK	1.93
9	Flagler CO	XFL	1.90
10	St Augustine	SGJ	1.88

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 38. Top prioritized airports Southwest Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Midland International	MAF	2.93
2	William P. Hobby	HOU	2.54
3	**Addison**	**ADS**	**2.51**
4	Albuquerque International	ABQ	2.30
5	Monroe Regional	MLU	2.22
6	Dallas Love Field	DAL	2.21
7	San Antonio International	SAT	2.16
8	**Tyler Pounds Regional**	**TYR**	**2.01**
9	**New Braunfels Municipal**	**BAZ**	**2.00**
10	**Easterwood Field**	**CLL**	**1.87**

Rankings do not include human and cultural factors
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 39. Top prioritized airports Southwest Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Midland International	MAF	3.48
2	William P. Hobby	HOU	3.18
3	Addison	ADS	3.04
4	**Laredo International**	**LRD**	**2.75**
5	Dallas Love Field	DAL	2.72
6	Tyler Pounds Regional	TYR	2.68
7	**Lea County Regional**	**HOB**	**2.56**
8	Albuquerque International	ABQ	2.53
9	San Antonio International	SAT	2.52
10	**Monroe Regional**	**MLU**	**2.51**

Rankings include human and cultural factors
Bold lettering represents addition of airport due to human and cultural factors

Table 40. Top prioritized airports Western Pacific Region – Ratio based prioritization

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	San Francisco International	SFO	3.09
2	**Los Angeles International**	**LAX**	**2.84**
3	McCarran International	LAS	2.77
4	North Las Vegas	VGT	2.74
5	Long Beach/Daugherty Field	LGB	2.67
6	Phoenix Deer Valley	DVT	2.51
7	Honolulu International	HNL	2.36
8	**Ernest A Love Field**	**PRC**	**2.09**
9	Gillespie Field	SEE	2.07
10	John Wayne	SNA	2.01

Rankings do not include human and cultural factors
Bold lettering indicates airports not initially represented in rank-ordered prioritization

Table 41. Top prioritized airports Western Pacific Region – Ratio based prioritization with human and cultural factors

Prioritization Ranking	*Airport*	*Airport Code*	*Aggregate Score*
1	Los Angeles International	LAX	3.97
2	Long Beach/Daugherty Field	LGB	3.81
3	San Francisco International	SFO	3.70
4	McCarran International	LAS	3.34
5	North Las Vegas	VGT	3.23
6	Phoenix Deer Valley	DVT	3.13
7	**Van Nuys**	**VNY**	**2.92**
8	**Monterey Peninsula**	**MRY**	**2.76**
9	John Wayne	SNA	2.75
10	Honolulu International	HNL	2.73

Rankings include human and cultural factors
Bold lettering addition of airport due to human and cultural factors

Chapter 5. Results and Analysis

5.1 Chapter overview

This chapter seeks to analyze the effect of the human and cultural factors on prioritization. A review of the FAA regional results including human and cultural factors will be conducted. Section 5.1 will focus on the rank-ordered and ratio based prioritization results. Section 5.2 will offer an in depth case study of Los Angeles International in the FAA Western Pacific region and the effect of the human and cultural factors.

5.2 Rank –ordered and ratio based prioritization results

As shown in chapter four, the human and cultural factors have a significant impact on the airport prioritization, through both a rearranged ranking of airports and addition and exclusion of airports. The following categories, for each FAA region, are of particular interest: top prioritized airports excluding human and cultural factors, top prioritized airports including demographic factors, airports removed and added from prioritization due to human and cultural factors, and airports ranked differently in prioritization due to human and cultural factors.

The purpose of this analysis is to examine the effect of the human and cultural factors is both a quantitative and qualitative manner. Quantitative results will focus on the number of airports affected by the human and cultural factors, while qualitative results will focus on the specific airports affected by the human and cultural factors. Airports are represented by their three letter identification code.

The results are presented in Tables 42-59 for both the rank-ordered and ratio based prioritization methods.

Table 42. Regional effect of human and cultural factors on rank-ordered prioritization – Alaska

Category	*Airports*
Top prioritized airports excluding human and cultural factors	MRI, JNU, FAI, ENA, BET, ANC, AKN, ADQ
Top prioritized airports including human and cultural factors	MRI, JNU, FAI, ENA, BET, ANC, AKN, ADQ
Airports removed from prioritization due to human and cultural factors	n/a
Airports added to prioritization due to human and cultural factors	n/a
Airports ranked differently due to human and cultural factors	n/a

Table 43. Regional effect of human and cultural factors on ratio based prioritization – Alaska

Category	*Airports*
Top prioritized airports excluding human and cultural factors	MRI, JNU, FAI, ENA, BET, ANC, AKN, ADQ
Top prioritized airports including human and cultural factors	MRI, JNU, FAI, ENA, BET, ANC, AKN, ADQ
Airports removed from prioritization due to human and cultural factors	n/a
Airports added to prioritization due to human and cultural factors	n/a
Airports ranked differently due to human and cultural factors	FAI, ADQ, BET, ENA, ANC

Table 44. Regional effect of human and cultural factors on rank-ordered prioritization – Central

Category	*Airports*
Top prioritized airports excluding human and cultural factors	TOP, STL, STJ, SLN, SGF, OJC, LNK, JLN, HUT, DSM
Top prioritized airports including human and cultural factors	STL, LNK, DSM, JLN, TOP, SUX, SUS, STJ, SLN, SGF, OMA, OJC, MHK, MCI, HUT
Airports removed from prioritization due to human and cultural factors	n/a
Airports added to prioritization due to human and cultural factors	SUX, SUS, OMA, MHK, MCI
Airports ranked differently due to human and cultural factors	TOP, STJ, SLN, SGF, OJC, HUT

Table 45. Regional effect of human and cultural factors on ratio based prioritization – Central

Category	*Airports*
Top prioritized airports excluding human and cultural factors	JLN, LNK, ALO, MCI, STL, DSM, GRI, OJC, BBG, ICT
Top prioritized airports including human and cultural factors	JLN, GCK, LNK, ALO, GRI, MCI, STL, DSM, SUX, BBG
Airports removed from prioritization due to human and cultural factors	ALO, OJC, ICT
Airports added to prioritization due to human and cultural factors	GCK, SUX
Airports ranked differently due to human and cultural factors	LNK, ALO, MCI, STL, DSM, GRI, OJC, BBG, ICT

Table 46. Regional effect of human and cultural factors on rank-ordered prioritization – Eastern

Category	*Airports*
Top prioritized airports excluding human and cultural factors	RIC, PIT, PHL, PHF, ISP, DCA, JFK, HPN, EWR, BWI
Top prioritized airports including human and cultural factors	ISP, PHL, DCA, RIC, PIT, PHF, JFK, HPN, EWR, TEB, RDG, MMU, BWI, ACY
Airports removed from prioritization due to human and cultural factors	n/a
Airports added to prioritization due to human and cultural factors	TEB, RDG, MMU, ACY
Airports ranked differently due to human and cultural factors	RIC, PIT, PHL, PHF, DCA, JFK, HPN, EWR, BWI

Table 47. Regional effect of human and cultural factors on ratio based prioritization – Eastern

Category	*Airports*
Top prioritized airports excluding human and cultural factors	PHL, EWR, PIT, DCA, TEB, ISP, JFK, ORF, BWI, IAG
Top prioritized airports including human and cultural factors	EWR, PHL, TEB, JFK, PIT, DCA, ISP, HPN, BWI, ORF
Airports removed from prioritization due to human and cultural factors	PHL, IAG
Airports added to prioritization due to human and cultural factors	HPN
Airports ranked differently due to human and cultural factors	PHL, EWR, PIT, DCA, TEB, ISP, JFK, ORF, IAG

Table 48. Regional effect of human and cultural factors on rank-ordered prioritization – Great Lakes

Category	*Airports*
Top prioritized airports excluding human and cultural factors	MSN, MKE, YIP, PWK, ORD, MSP, MIC, MDW, LUK, DTW
Top prioritized airports including human and cultural factors	MSN, MKE, PWK, ORD, MSP, MIC, MDW, DTW, YIP, STP, LUK, LAF, FCM
Airports removed from prioritization due to human and cultural factors	n/a
Airports added to prioritization due to human and cultural factors	STP, LAF, FCM
Airports ranked differently due to human and cultural factors	YIP, LUK

Table 49. Regional effect of human and cultural factors on ratio based prioritization – Great Lakes

Category	*Airports*
Top prioritized airports excluding human and cultural factors	ORD, MIC, MSP, MKE, DTW, MDW, YIP, LUK, OSH, FCM
Top prioritized airports including human and cultural factors	ORD, MIC, MSP, MDW, MKE, PWK, DTW, MSN, FCM, YIP
Airports removed from prioritization due to human and cultural factors	LUK, OSH
Airports added to prioritization due to human and cultural factors	PWK, MSN
Airports ranked differently due to human and cultural factors	MKE, DTW, MDW, YIP, LUK, OSH, FCM

Table 50. Regional effect of human and cultural factors on rank-ordered prioritization – New England

Category	*Airports*
Top prioritized airports excluding human and cultural factors	PWM, PVD, OWD, MHT, LWM, HYA, HFD, DXR, BTV, BOS, BED, BDL
Top prioritized airports including human and cultural factors	PVD, OWD, MHT, LWM, HYA, HFD, DXR, BOS, BED, BDL
Airports removed from prioritization due to human and cultural factors	PWM
Airports added to prioritization due to human and cultural factors	n/a
Airports ranked differently due to human and cultural factors	PWM

Table 51. Regional effect of human and cultural factors on ratio based prioritization – New England

Category	*Airports*
Top prioritized airports excluding human and cultural factors	BOS, BTV, PWM, BDL, HFD, BED, MHT, OXC, HYA, ACK
Top prioritized airports including human and cultural factors	BOS, PWM, BDL, BED, HFD, BTV, MHT, OXC, PVD, EWB
Airports removed from prioritization due to human and cultural factors	HYA, ACK
Airports added to prioritization due to human and cultural factors	PVD, EWB
Airports ranked differently due to human and cultural factors	BTV, PWM, BDL, BED, HYA, ACK

Table 52. Regional effect of human and cultural factors on rank-ordered prioritization – Northwest Mountain

Category	*Airports*
Top prioritized airports excluding human and cultural factors	PVU, PAE, OGD, BIL, PUB, PDX, HLN, BJC, APA, SLC, SEA, PDT, OLM, EUG, CPR, BZN
Top prioritized airports including human and cultural factors	BIL, PVU, PUB, PDX, PAE, OGD, HLN, BJC, APA, YKM, SUN, SLC, SEA, PDT, MWH, EUG, CPR, BZN, ALW
Airports removed from prioritization due to human and cultural factors	OLM
Airports added to prioritization due to human and cultural factors	YKM, SUN, MWH, ALW
Airports ranked differently due to human and cultural factors	PVU, PAE, OGD, OLM,

Table 53. Regional effect of human and cultural factors on ratio based prioritization – Northwest Mountain

Category	*Airports*
Top prioritized airports excluding human and cultural factors	PDT, SLC, APA, OGD, OTH, DEN, ASE, PAE, SEA, HLN
Top prioritized airports including human and cultural factors	PDT, APA, DEN, SLC, MWH, ASE, PSC, BJC, BIL, OGD, OTH, SEA, PDX
Airports removed from prioritization due to human and cultural factors	PAE, HLN
Airports added to prioritization due to human and cultural factors	MWH, PSC, BJC, BIL, PDX
Airports ranked differently due to human and cultural factors	SLC, APA, OGD, OTH, DEN, ASE, PAE, SEA, HLN

Table 54. Regional effect of human and cultural factors on rank-ordered prioritization – Southern

Category	*Airports*
Top prioritized airports excluding human and cultural factors	PDK, MIA, FLL, CVG, CLT, VRB, TPA, SFB, XFL, SJU, SDF, FXE, DAB
Top prioritized airports including human and cultural factors	PDK, MIA, FLL, CVG, CLT, VRB, TPA, SJU, SFB, FXE
Airports removed from prioritization due to human and cultural factors	XFL, SDF, DAB
Airports added to prioritization due to human and cultural factors	n/a
Airports ranked differently due to human and cultural factors	CVG, CLT, VRB, TPA, SFB, XFL, SDF, DAB

Table 55. Regional effect of human and cultural factors on ratio based prioritization – Southern

Category	*Airports*
Top prioritized airports excluding human and cultural factors	CLT, PIE, MIA, ATL, FLL, SGJ, PDK, HWO, XFL, VLD
Top prioritized airports including human and cultural factors	CLT, MIA, PIE, ATL, FLL, VLD, HWO, PDK, XFL, SGJ
Airports removed from prioritization due to human and cultural factors	n/a
Airports added to prioritization due to human and cultural factors	n/a
Airports ranked differently due to human and cultural factors	PIE, MIA, SGJ, PDK, HWO, VLD

Table 56. Regional effect of human and cultural factors on rank-ordered prioritization – Southwest

Category	*Airports*
Top prioritized airports excluding human and cultural factors	TUL, DAL, ABQ, SAT, MLU, MAF, LFT, HOU, BTR, SJT, HOB, CRP
Top prioritized airports including human and cultural factors	DAL, TUL, MLU, MAF, HOU, HOB, BTR, ABQ, SAT, LFT
Airports removed from prioritization due to human and cultural factors	MAF, SJT, CRP
Airports added to prioritization due to human and cultural factors	n/a
Airports ranked differently due to human and cultural factors	TUL, ABQ, SAT, LFT, SJT, HOB, CRP

Table 57. Regional effect of human and cultural factors on ratio based prioritization – Southwest

Category	*Airports*
Top prioritized airports excluding human and cultural factors	MAF, HOU, ADS, ABQ, MLU, DAL, SAT, TYR, BAZ, CLL
Top prioritized airports including human and cultural factors	MAF, HOU, ADS, LRD, DAL, TYR, HOB, ABQ, SAT, MLU
Airports removed from prioritization due to human and cultural factors	BAZ, CLL
Airports added to prioritization due to human and cultural factors	LRD, HOB, MLU
Airports ranked differently due to human and cultural factors	ABQ, MLU, DAL, SAT, TYR, BAZ, CLL

Table 58. Regional effect of human and cultural factors on rank-ordered prioritization – Western Pacific

Category	*Airports*
Top prioritized airports excluding human and cultural factors	SNA, HNL, SFO, PRC, CNO, VGT, TUS, STS, SEE, RYN, RNO, MYF, LGB, LAS, IWA, DVT
Top prioritized airports including human and cultural factors	SNA, HNL, CNO, VNY, SFO, PRC, LGB, WHP, VGT, TUS, STS, SEE, RYN, RNO, RDD, PSP, POC, MYF, MRY, LAX, LAS, IWA, DVT
Airports removed from prioritization due to human and cultural factors	n/a
Airports added to prioritization due to human and cultural factors	VNY, WHP, RDD, PSP, POC, MRY, LAX
Airports ranked differently due to human and cultural factors	HNL, SFO, PRC, VGT, TUS, STS, SEE, RYN, RNO, MYF, LAS, IWA, DVT

Table 59. Regional effect of human and cultural factors on ratio based prioritization – Western Pacific

Category	*Airports*
Top prioritized airports excluding human and cultural factors	SFO, LAX, LAS, VGT, LGB, DVT, HNL, PRC, SEE, SNA
Top prioritized airports including human and cultural factors	LAX, LGB, SFO, LAS, VGT, DVT, VNY, MRY, SNA, HNL
Airports removed from prioritization due to human and cultural factors	PRC, SEE
Airports added to prioritization due to human and cultural factors	VNY, MRY
Airports ranked differently due to human and cultural factors	SFO, LAX, LAS, VGT, LGB, HNL, PRC, SEE, SNA

5.3 Los Angeles International Airport: case study

Los Angeles International Airport (LAX) is one of the busiest airports in the nation with over thirty million passenger boardings and yearly operations well over half a million. In Fiscal Year 2011, LAX recorded nearly twenty runway incursions of varying degrees, placing it in the top three for recorded incursions in the FAA Western Pacific Region.

Despite the clear level of risk present at this airport, the rank-ordered framework, absent human factors, failed to identify LAX as a top prioritized airport. Two issues presented below are responsible for this exclusion. These issues are accounted for in the ratio based human factors inclusive framework.

1. The failure of the rank-ordered method to account for varying levels of airport characteristics in factor categories
    a. LAX ranks highest in yearly operations by a significant amount. The majority of airports in the region have an operations count many orders of magnitude lower
    b. LAX ranks third highest in total incursions. Only a select few airports in the region recorded more than ten incursions
2. The failure of the prioritization framework to account for human factors
    a. A review of the incursion database suggests incursions stemming from ground vehicle error, including baggage carts and tow vehicles
    b. Additional incidents appear to be the result of miscommunication, including "garbled" messages from air crew on foreign carriers

The updated frameworks, used to generate the rankings shown in Tables 23 and 41, correct for these issues, as LAX is a highly prioritized airport for both the rank-ordered and ratio based methods. This highlights the effectiveness of the new prioritization methods and suggests the methods represent a more thorough approach.

Chapter 6. Discussion

6.1 Chapter overview

This chapter provides a discussion of the overall thesis results as well as specific topics. The goal is to gain a further understanding of those aspects involved in the development and execution of the work presented in this thesis. Many of the discussion items are drawn directly from conversation and interaction with FAA officials, aviation officials and others in academic positions. Section 6.2 will focus on alternative approaches to runway safety. Section 6.3 will focus on the use of English proficiency and ground vehicle operations as factors. Section 6.4 will focus on the use of a prioritization framework.

6.2 Alternative runway safety approach

The prioritization methods presented in this thesis are effective in identifying airports with a potentially higher risk for runway incidents. The identification and incorporation of relevant factors can help in resource allocation and risk management. While the elimination or restructuring of those components which directly threaten runway safety represents the most comprehensive approach to ensuring safety, often, real world limitations prevent immediate and effective action. The complexity and multifaceted nature of airport systems can often delay attempts to address the contributing causes of incidents. Many stages, from initial identification to testing, must be completed prior to the implementation of large-scale changes. For example, on grounds vehicle tracking systems have been in identification and testing phases for several years; however, their use on airport grounds is not yet completely universal. Another example is the renewed dedication to reforming English testing procedures to better improve the standards of aviation focused English. These types of comprehensive changes, while often necessary and beneficial, require relatively large periods for implementation, time in which a runway system remains vulnerable to incidents and safety failures.

A prioritization method allows for immediate identification of high risk airports and can be used to effectively allocate valuable resources (RSAT meetings). These resources can be used as a catalyst for immediate action, which can improve safety of high risk airports. Simultaneous efforts can focus on long term comprehensive changes, similar to those mentioned above. Short and long term approaches must be utilized for effective management of risk.

6.3 Identification and quantification of human factors

The human and cultural factors presented in this thesis are potential contributors to several types of runway incursions. Studies and practice confirm the role that communication, specifically proficient English, and ground vehicle operations play in ensuring runway safety. The approach presented in this thesis is by no means comprehensive in modeling the role of human factors in runway safety; however, the methods offered represent an initial step in incorporating human factors for prioritization of runway safety.

The somewhat qualitative and subjective nature of the human factors relevant to runway safety is one of the primary challenges in quantifying and incorporating a class of human and cultural factors. It can be difficult to accurately determine the extent to which these factors are present on airport grounds. Additionally, a lack of centralized data and significant diversity, in terms of the entities and organizations operating on airports grounds, represents another significant challenge. For these reasons, the demographic characteristics of the population surrounding an airport are used to quantitatively and uniformly identify these factors.

The English proficiency rate of the surrounding population is valuable for a number of reasons. The census data used to identify this rate is available for the regions surrounding all FAA airports, and it contains specific questions addressing language characteristics. As shown earlier in this thesis, for a geographically diverse collection of airports, an increased non proficient English rate is highly correlated with an increase in international flights. This suggests that regions with higher language heterogeneity are likely to see higher rates of international flights and have a greater risk of subsequent miscommunication. Additionally, it is likely that the permanent airport workforce is drawn from the surrounding population, and will share, to some extent, many of the demographic characteristics in the surrounding population. Airports in more demographically diverse regions may have a higher risk of incidents stemming from miscommunication and non-English proficiency.

In the same manner that the surrounding population is used to better understand the English proficiency characteristics of those working on airport grounds, it can be used to better understand the driving characteristics of those operating vehicles on airport grounds. A surrounding population with a higher fatal vehicle accident rate is likely to be associated with less responsible, attentive and safe drivers. The operators of vehicles on airport grounds are drawn both directly and indirectly from this population. Therefore, it is likely that airports in regions with higher accident rates may have a higher risk of incursion due to ground vehicles.

The use of the surrounding population can be helpful in the identification of risk due to human and cultural factors and can be used for a relative comparison of airports.

6.4 Factor based approach

The factor based approach used for prioritization of airports for runway safety audits is an effective method for identifying high risk airports. There are several reasons for the development of a factor based prioritization method rather than simply responding to previous instances of runway incursion. By responding to previous incidents of runway incursion, risk management is replaced by incident response. Through a more comprehensive factor based approach, airports with greater risk can be highlighted and resources can be pro-actively allocated. It is also important note that previous incursion rates are taken into account in the prioritization framework. Additionally, the sparse nature of incursions can also lead to misleading conclusions with respect to the incursion rate and state of runway safety at an airport. For example, an airport with a small number of yearly operations might see an abnormal increase in the incursion rate due to a low severity, non-systematic runway incursion. While the historical incursion rate should be involved in the prioritization effort, it should not represent the entire approach.

Chapter 7. Summary and Conclusions

7.1 Summary of Contributions

This thesis seeks to develop methods to identify, quantify and incorporate human and cultural factors to a prioritization framework for the risk management of runway systems. Demographic factors of the populations surrounding airports are used to aid in identification and quantification of the human and cultural factors. Rank-ordered and ratio based prioritization frameworks are used to test the implications of risk management through identification of airports that are affected by the inclusion of the human and cultural factors. While this method is by no means representative of all human and cultural factors relevant to runway safety, it represents an initial effort to incorporate aspects of human and cultural factors into priority setting frameworks. An updated roadmap of the technical approach is shown in figure 24, with reference to the specific chapters in which the steps are addressed.

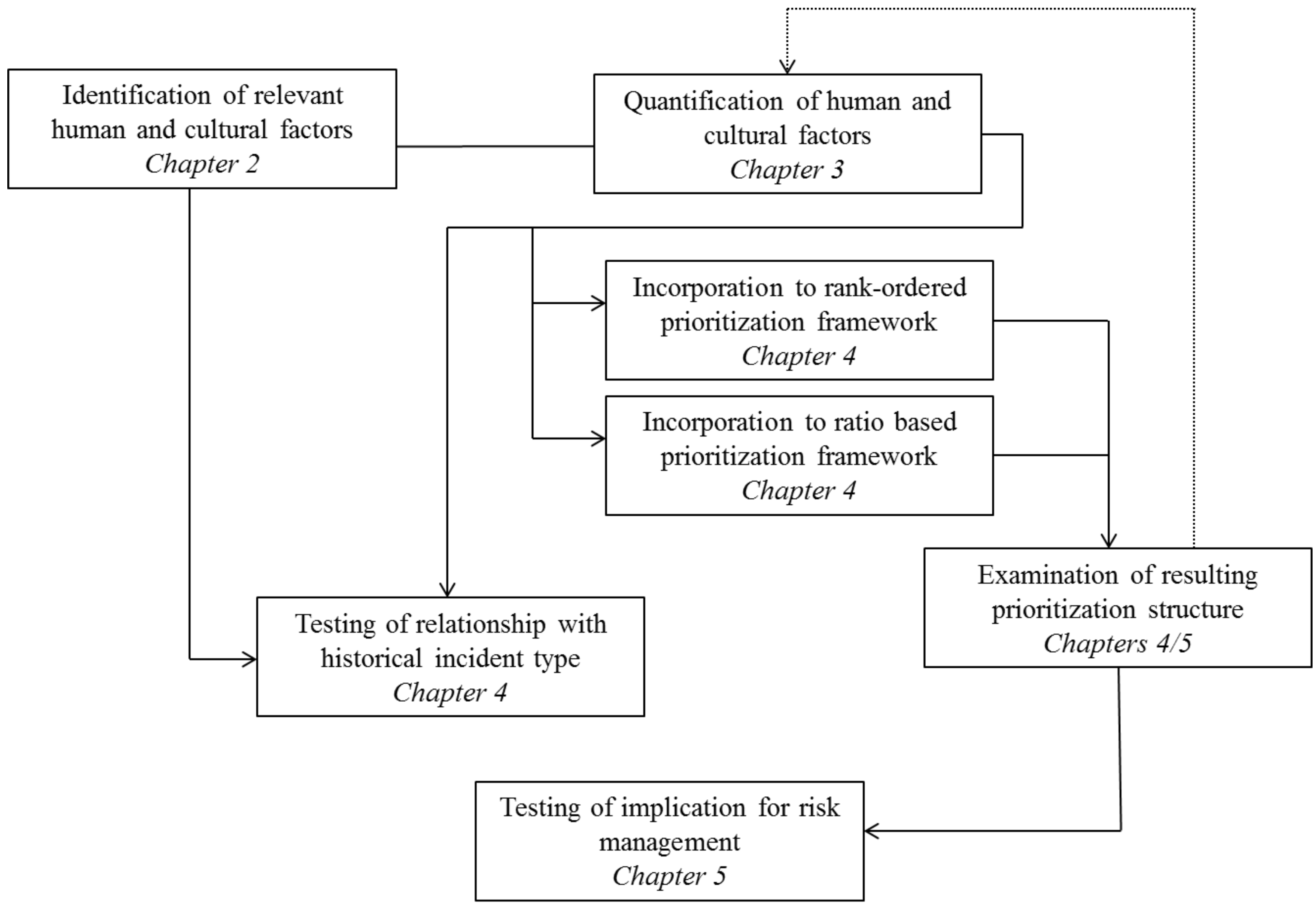

Figure 24: Roadmap of technical approach to select and demonstrate the use of demographic factors for prioritizing airports for runway safety audits with reference to relevant chapters

A summary of the contributions of this thesis are presented below.

- **Introduction of human and organizational factors to prioritize regulatory safety audits to airports.**

Previous work focused on a prioritization framework based on physical features and historical operational statistics. While this represents a substantial initial step, it does not account for the greatest threat to runway safety: human and cultural factors. This thesis introduces methods for incorporation of these factors

- **Introduction and demonstration of the use of population English proficiency as a metric.**

Observation, expert elicitation and a review of aviation based literature identified miscommunication and misinterpretation as a contributor to runway incursions. A deeper analysis highlighted a lack of English proficiency as a likely contributor to miscommunication. Language characteristics of surrounding populations are used to develop an understanding of demographics of those operating on airport grounds.

- **Introduction and demonstration of the use of off-airport crash statistics as a metric.**

A thorough investigation also identified the importance of ground vehicle operations in runway safety. Safe and responsible operation of vehicles on airport grounds is essential. Driving characteristics of the surrounding population are used to better understand the operation of vehicles on airport grounds.

- **Exploration of the relationships of the above metrics to actual incident frequencies, admitting these are rare events and the data are sparse.**

Runway incursions are rare events and a lack of extensive data can challenge efforts to identify relationships between factors and incidents. However, exploratory analysis can support that factors are not negatively correlated, a sufficient step for the purpose of this work.

- **Development of a ratio based prioritization framework airport safety audits**

Previous attempts to develop a prioritization framework rely on a rank-ordered method. The combination of factors based on a ratio scale and a rank-order prioritization method can be problematic. Therefore a ratio based prioritization method is introduced and utilized.

- **Integration of new factors to a multicriteria priority-setting framework and testing of the implications for risk management, i.e., finding which airports would have been missed by the earlier approaches that did not address human and organizational factors.**

An analysis highlights the effect of the inclusion of the human factors class on the prioritization effort. For all nine FAA Regions a comparison of prioritized airports, using both rank-ordered and ratio based methods, is shown to highlight airports which benefit from the inclusion of the human factors class

7.2 Future Work

A prioritization framework can address the multifaceted and emergent nature of large-scale systems through an effective use of an inventory of system assets (Leung et. al, 2004). Identification of those factors relevant to system safety represents a significant challenge, and incorporation of those factors into a prioritization framework substantially increases this challenge. Additionally, methods used to identify and incorporate human factors, perhaps the greatest threat to large-scale complex systems, are not formally defined and lack a significant presence in previous prioritization efforts. With the increase in technical capability and reliability of complex systems, it is necessary to address this human factors aspect. The methods described and presented in this thesis can be directly implemented and utilized in this context. The quantification techniques presented in this thesis can be utilized to support adaptive risk management through the update and recollection of data used to represent the human and cultural factors. Transportation, manufacturing, healthcare and other complex systems would benefit significantly from this adaptive and objective approach to addressing human and cultural factors.

Future work can be focused in several directions to build upon techniques and methods presented in this thesis. While the two factors presented in this thesis are likely contributors to instances of runway incursions, further work could focus on an expansion to include more human and cultural factors. Further relevant demographic data could be gathered and analyzed for its effect on runway safety. If identified, these factors could be incorporated into the prioritization framework in a manner consistent with the other human factors.

Efforts by the FAA to reduce punitive actions in instances of runway incursion reporting will likely lead to more accurate and comprehensive information regarding runway incursions

(FAA, 2008). A larger and more comprehensive data set will allow for further testing of relationships between identified human and cultural factors and historical runway incursions.

Additional efforts can focus on improving and reconfiguring those aspects of the runway system which contribute most to increased risk. For example, fundamental restructuring of airport procedures could eliminate the presence of ground vehicles in certain problematic areas, more comprehensive language assessment could lead to less communication error, and renewed focus on operating procedures could lead to safer driving habits.

While future efforts to improve safety though systematic changes are likely to occur, the risked based prioritization methods and techniques presented in this thesis can be utilized immediately for effective risk management.

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Appendix

IAD RUNWAY SAFETY ACTION TEAM MEETING MINUTES

OVERVIEW

On May 17, 2012, Dulles Tower in conjunction with Metropolitan Washington Airports Authority (MWAA) hosted a Runway Safety Action Team (RSAT) Meeting at Washington Dulles International Airport. Jim Slate, Air Traffic Manager, facilitated the meeting. The purpose of the meeting was to review past surface incidents, discuss risks and actions that could prevent their reoccurrence, increase safety awareness, and update the Runway Safety Action Plan (RSAP).

The RSAP, list of attendees, meeting agenda and handouts are appended to these minutes.

OPENING STATEMENTS AND INTRODUCTIONS

Jim Slate gave some introductory remarks, highlighting the priority that the FAA places on preventing runway incursions. He also mentioned that the FAA is collecting much more safety data than ever before because of new reporting programs that exclude punitive actions. He then went around the room and asked attendees to introduce themselves.

AIR TRAFFIC PRESENTATION – Jim Slate, Air Traffic Manager, Dulles TWR

Statistics on nationwide runway incursions by type:

(May thru Apr)	OI	PD	V/PD	TOT
2009-2010	156	606	188	950
	17%	64%	19%	
2010-2011	181	646	193	1020
	18%	63%	19%	+1.1%
2011-2012	140	486	143	Awaiting Apr '12 Results
(as of 3/16)	18%	63%	19%	

OI = Operational Incidents (ATC)

PD = Pilot Deviation

V/PD = Vehicle or Pedestrian Deviation

Members were asked to review the handouts (appendix C) for completeness and correctness. They were also encouraged to visit the display table which had a wealth of information relating to airfield signs, runway/taxiway markings, driving on the airport, hotspots, ATC phraseology, and more.

The definition and categories of runway incursions was reviewed. These were included in the handouts.

Table of IAD Surface Events that occurred during the last 4 years:

CY	Surface Incident	Runway Incursion	Category	Type Incident
2008	2	5	1B, 4D, 2E	1 OE, 6 PDs
2009	0	9	7C, 1D,1E	3 OEs, 4 PDs, 2 V/PDs
2010	0	3	1C, 2D	1 OE, 1 PD, 1 V/PD
2011	1	6	1C, 5D, 1NA	5 PDs, 2 V/PDs
2012(to date)	0	3	(3 to be assigned)	1 PD, 2 V/PDs
Total	3	23	1B,9C,12D, 3E 1NA (3 unassigned)	5 OE's, 17 PDs, 7 V/PDs

Figure 25: Page one of notes from FAA RSAT meeting conducted at Dulles International Airport in 2012

Review of Runway Incursions since May '10:

Pilot Deviations (5)

1. MD88 entered & departed RY19L w/o ATC clearance. No aircraft on final. (Cat D)
   - FSDO report showed loss of situational awareness (SA) as reason.
2. LJ60 entered RY30 w/o ATC clearance. E170, cleared for takeoff full length did not start takeoff roll. (Cat C)
   - Confusion over ATC clearance. PIC thought ATC should have said "hold short."
3. GA aircraft entered RY19C w/o ATC clearance. Exited at Y1. No conflicts. (Cat D)
   - No reason given on FSDO report.
4. International carrier went line-up-and-wait (LUAW) RY1R w/o ATC clearance. Exited at K8. Aircraft on 3.6 mile final was allowed to continue. (Cat D)
   - Reason for the confusion is not known.
5. C182 got disoriented after landing RY 19C. ASDE-X video clip was shown of aircraft reversing course on Y2, turning back toward the runway and exiting at Y3. Since aircraft never left the RSA, this was not a runway incursion.
   - FSDO report showed pilot to be fatigued, disoriented, and distracted by an incorrectly initialized Garmin 1000 Safe Taxi System.

Reminders were given about -- hold lines, clearances required to - cross, taxi onto, LUAW, or takeoff from a runway; the absence of 'hold short' instructions does not allow an aircraft to proceed onto the departure runway; and, after landing runway exiting expectations.

Additionally -- crews were reminded to review the airport diagram; know signage, pavement markings and lights; listen up, avoid distractions, and readback clearances using the call sign.

Vehicle/Pedestrian Deviations (3)

1. A maintenance tug crossed RY 19C without ATC clearance after thinking they were approved to proceed to 'Ramp B'. No loss of separation. (Cat D)
   - Confusion over the terms 'Ramp B', 'Bravo Ramp', and 'Apron B'. MWAA changed the name to 'Apron W'.
2. (and 3.) An SUV, not capable of communicating with tower, crossed RY 1C twice -- going to and coming from Apron W. During both incursions, there were aircraft on short final for RY1C. (Categories not yet assigned)
   - The RSAT members viewed the surface radar (ASDE-X) video replays which showed how close the two aircraft on RY 1C final were to the threshold. ATC did not observe the first (westbound) crossing, nor was there any safety logic alert. The arrival did not report the crossing.
   - Three minutes later, the eastbound crossing triggered an ASDE-X safety logic alert. LCL sent the aircraft around.
   - MWAA mitigations:
     - A memo was sent to all stations advising them to avoid the Apron W area during space shuttle operations. The memo attached pictures of stop signs,

Figure 26: Page two of notes from FAA RSAT meeting conducted at Dulles International Airport in 2012

cones, pavement markings, and runway guard lights. These were shown to RSAT members as well.

- The Airfield Vehicle Control Program was updated and is awaiting FAA approval.
- The Non-Movement Area and Movement Area Training Videos, now an annual requirement, are being updated. MWAA would like to include video replays such as the ones shown above.
- Pictures were handed out depicting new hold short signs which were installed on each vehicle service road leading to a runway only.

NASA ASRS Report (1)

1. Airport personnel made a request to enter the runway safety area (RSA) near a high speed taxiway to repair a damaged sign. The vehicle operator mistook the controller's response, "roger", as approval to enter the RSA. An aircraft had been cleared LUAW on that runway.
   - The definition of the phrase 'roger' was discussed and phraseology examples were presented.

Birds/Wildlife/FOD (as reported to tower)

Period	# Incidents	Birds	Other Wildlife	FOD	Ops Susp.	Avg (min)	Aborts	Go Arounds	Damage Rpt'd
'10 – '11	111	58	6	47	88	8.5	0	17	6
'11 – '12	70	54	7	9	53	7.5	2	6	1

It was noted that the number of incidents was reduced significantly, especially FOD. For the last three years, the average minutes that operations on the runway were suspended has decreased from 12.5 minutes to 7.5 minutes.

Ryan Stewart, USDA's Wildlife Biologist at IAD, reported that damaging strikes declined from 9 in 2010 to 4 in 2011 with aircraft movements remaining fairly steady over that period and bird survey counts higher than 2010. He added that IAD should expect more coyotes, foxes, and raptors due to increased small mammal population resulting from the mild winter.

There were no deer observed within the AOA in 2011. The last deer observation/removal from the AOA was 11/1/10. The next Wildlife Hazard Work Group meeting is set for June.

Enhancements to Runway Safety

ATC Phraseology & Procedural changes -- at airports where there is a temporary or permanent change to runway length due to construction:

- ATIS shall include the word 'WARNING' prefacing the runway number and ensure the term 'shortened' is included in the text of the message. Also include available runway length.
- The term 'full length' shall not be used until the A/FD has been changed.
- For line up and wait, takeoff, and landing clearances -- add the word 'shortened.'

Figure 27: Page three of notes from FAA RSAT meeting conducted at Dulles International Airport in 2012

RUNWAY STATUS LIGHTS (RWSL) PRESENTATION – Bill Leary, Program Office

Bill explained the operation of RWSL components – Runway Entrance Lights (REL) and Take-off Hold Lights (THL) and pointed out where they are installed at IAD.

- Currently at BOS, DFW, LAX, & SAN. The legacy system is now online at MCO.
- REL's are a series of red lights embedded in the pavement to warn pilots and vehicle operators if it is unsafe to cross over or enter a runway.
- THL's are in-pavement lighting aligned with runway centerline extending for 1500'. Illuminated red lights indicate to an aircraft in position for takeoff or rolling that it is unsafe to takeoff because the runway is occupied or about to be occupied by an aircraft or vehicle.
- Runway Status Lights only indicate if a runway is unsafe to enter or take-off.
- All clearances will still be issued by ATC.
- If the runway status lights conflict with an ATC clearance pilots should hold their position and advise ATC they are holding due to red lights.
- 23 ARPTS by 2015

RWSLs are expected to be operational at IAD in early 2013.
Bill offered his services to those who wish RWSL training at their facilities. (202-486-6259)

MWAA OPERATIONS PRESENTATION – Janene Shaw – MWAA Operations Officer

In addition to the Vehicle Control Program initiatives and new signage, Janene mentioned the following upcoming construction projects:
- Taxiway Y, Z and the high speed taxiways for Runway 1C/19C -- the airfield signs will have asphalt placed around them;
- A new water line will be installed, limiting Taxiway J between C & E to Group IV;
- Taxilane E, at Spot 83 will be closed for approx. 10 days to install a new water line;
- Runway 12/30 will be closed for approximately 3 days to widen, mill and overlay the 30 Blast Pad;
- Spring/Summer 2013, Taxiway Y between Taxiway C & Y4 will be reconstructed.

UPDATE OF CURRENT RUNWAY SAFETY ACTION PLAN (RSAP)

Action Item Code: IAD-2011-001
Completion Date: 5/31/2012
Status: Active

Action Item: The controller's handbook requires detailed taxi instructions be issued to all aircraft. Clearances for aircraft taxiing from RY1L/19R to their gates can have many elements (including hold short instructions). This occurs regardless of whether aircraft are to cross the center runway or taxi around the south end via taxiway Q. Extensive verbiage on frequency can detract from higher priority duties. In addition, some aircraft continue to request exiting on "reverse" highspeed taxiways, which has resulted in go-arounds. Air Traffic is requested to no longer allow these, and to incorporate high speed taxiways in their abbreviated routes. A workgroup will be formed to see if creating abbreviated taxi routes would alleviate long clearances and enhance runway safety.

Responsible party: Jim Slate, FAA, Air Traffic Manager.
Responsible for SRM: Jim Slate

Figure 28: Page four of notes from FAA RSAT meeting conducted at Dulles International Airport in 2012

5/17/12 Update: Jim Slate

A workgroup was formed and is currently meeting. Its scope is to *first* find out what route will be used to taxi aircraft from the far west runway, 19R/1L. Will aircraft be taxied across the center runway or around it via taxiway Q? And – if crossing a runway, will aircraft be on ground control or local control frequency? Once these questions are answered and procedures are set up, only then can IAD-2011-001, abbreviated routes, be addressed. The workgroup results are expected in June.

This item will remain on the IAD RSAP.

DISCUSSION OF NEW ISSUES AND SAFETY CONCERNS

- Runway Safety Inspection Out Briefing:

On 5/15/12, 8 RSAT members toured the airfield with a focus on signage, pavement markings, and lighting as they pertain to runway safety. Comments and concerns:

- Runway guard lights (wig-wags) – designed to be visible from flight deck; vehicle drivers may have problems seeing them flashing when up close.
- Aircraft turning right vs. left when approaching Y11 enroute to RY30 – Yellow in pavement marking was shown to the group; one member did not remember seeing it when taxiing by; MWAA used to have a sign pointing to RY30 but it blew over. It was not reinstalled because there was no feedback on whether it was useful.
- RY 1C Approach pavement markings were observed.

All agreed that the airfield tour was beneficial.

- Group Discussion:
  - Reference the Y11 confusion – mostly occurs when crew is unfamiliar with airfield. Can be mitigated if GC issues full clearance to RY30 -- including taxiway Q – and by monitoring the aircraft's progress. RSAT will continue to monitor.
  - Reference the RI's above -- IAD NATCA Rep. offered a possible explanation for why local controllers did not add the phrase 'hold short' when repositioning traffic near the runway -- -- the fear that they will get in trouble for not ensuring a readback of hold short instructions when they weren't required to issue them to begin with. National and local audits to ensure readback of hold short instructions may be having the reverse effect on runway safety.
  - One member, a pilot, mentioned that the pavement markings for the 1C and 1L Approach Obstacle Clearance Surface Areas are the same as runway hold short markings. This can lead to confusion as pilots are taught to not cross hold lines. He said he is on the FAA work group that is addressing this issue and will keep us informed.
  - The MWAA Fire and Rescue Chief mentioned that they are changing the nomenclature and numbering of their vehicles to improve radio communications. The numbers will be painted on top and each vehicle will have a unique call sign. They hope to be included on the list of vehicles that will receive transponders.
  - The chief also mentioned that the training session with ATC staff regarding LOA and general airfield procedures/communications was very beneficial. He hopes that they can be held every six months.

Figure 29: Page five of notes from FAA RSAT meeting conducted at Dulles International Airport in 2012

Figure 30: Map of nine designated FAA regions

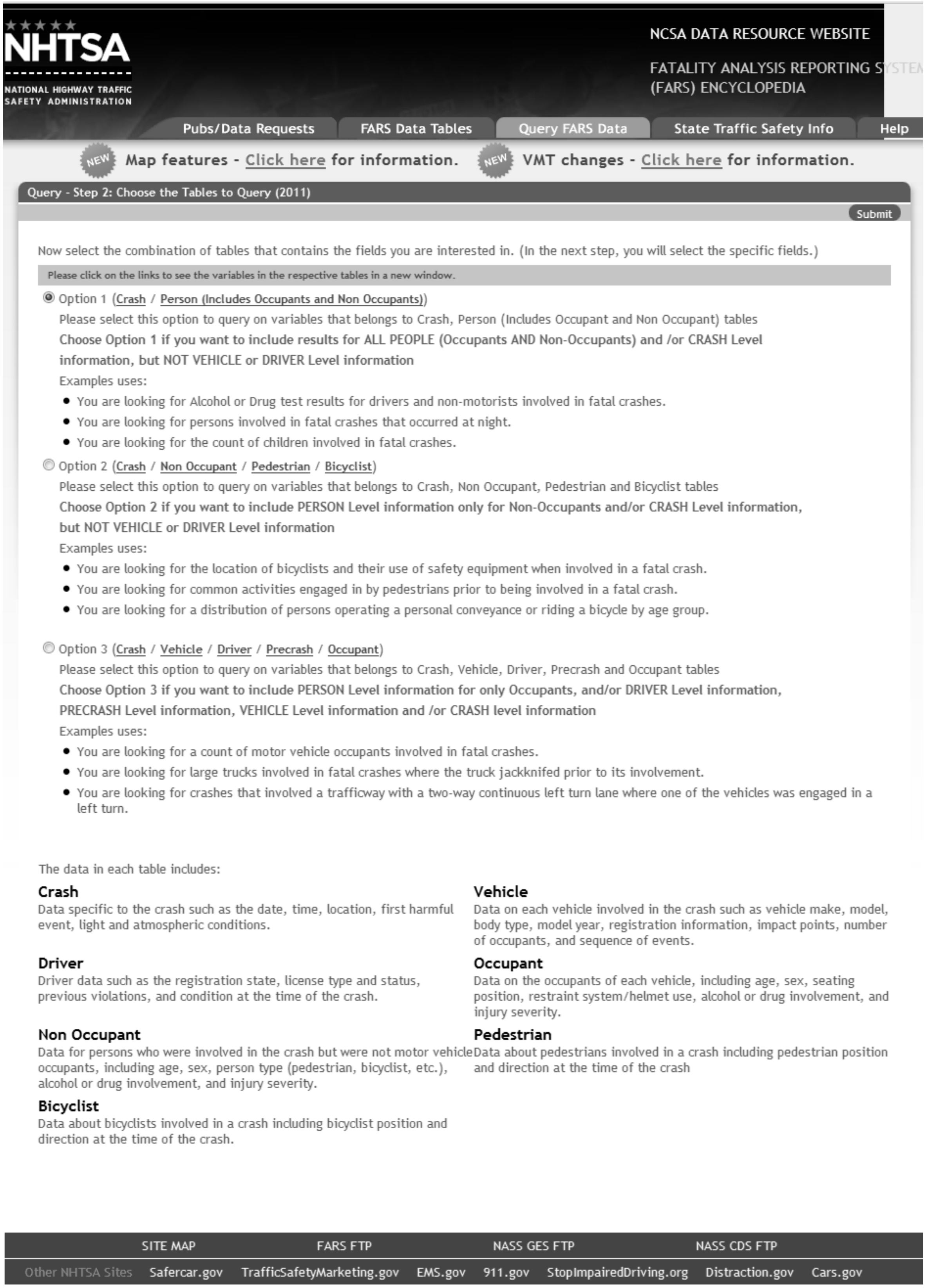

Figure 31. Screenshot of FARS encyclopedia query page used in identifying commercial vehicle related fatal accidents in the populations surrounding airports

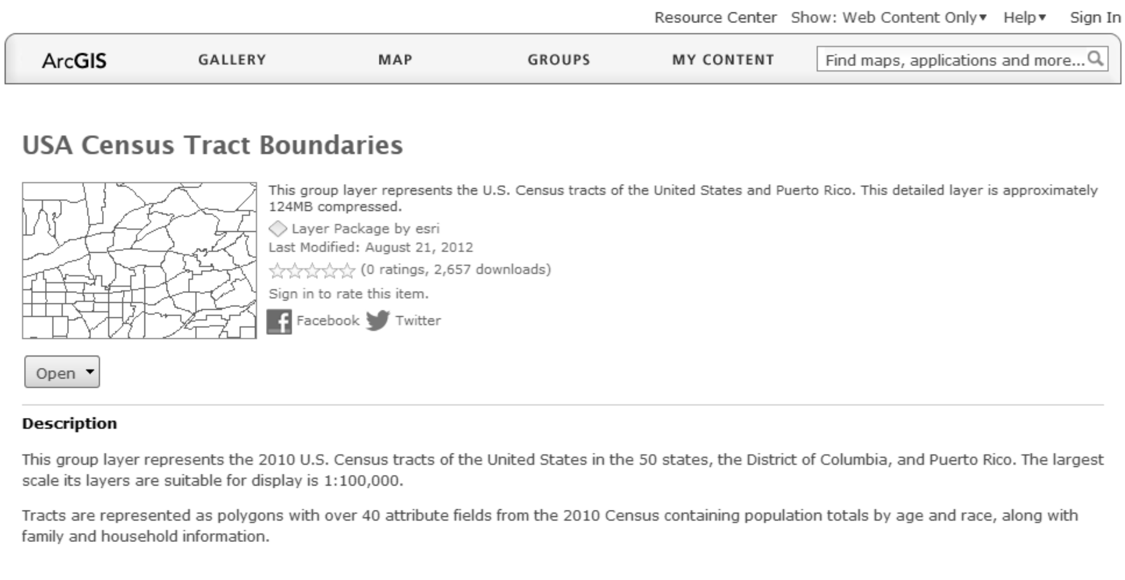

Figure 32. Screenshot of ArcGIS page used in identifying English proficiency in the population surrounding airports