Exploring the Effect of Human Factors Regulations on Aviation Maintenance Organizations

Dissertation

Submitted to Northcentral University

Graduate Faculty of the School of Business and Technology Management
in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

by

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Prescott Valley, Arizona
March 2011

APPROVAL PAGE

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Abstract

United States (U.S.) aviation officials estimated that 15% of aircraft accidents result from mechanic error and these errors arise from poor human factors practices. The United Kingdom's (U.K.) aviation officials recognized the effects of poor human factors practices, but implemented regulations to control human factors practices and reduced the U.K. accident rate to 6%. A quantitative, ex post facto analysis of accident rates was used to investigate the problem of the higher U.S. rate when compared to the U.K. rate. No human participants were involved; samples of accident reports were taken from the U.K. databases before and after the implementation of the regulation. An analysis of sampled reports determined the accident rate in each sample and a chi-square analysis compared these rates to ascertain the effect of regulations in the U.K. The chi-square analysis detected no significant difference in U.K. accident rates before and after regulation, $\chi^2(1, N = 276) = 1.27, p = .26$. To provide for data triangulation, U.S. accident records underwent an identical sampling and analysis procedure yielding an accident rate suitable for comparison to the U.K. rate. These U.K. and U.S. rates were used in a chi-square comparison of nations with and without regulations; no significant difference was detected, $\chi^2(1, N = 276) = .85, p = .36$. In the comparison between U.K. and U.S. data, accident rates in both nations declined by similar amounts (6% and 5%, respectively) despite the absence of regulation in the U.S. In this study, human factors regulations did not significantly affect the U.K. maintenance related accident rate. The study findings did not support institutionalism theory. This research was limited to two national aviation systems; future research efforts might expand this comparison to other nations to provide more information about the effect of human factors regulations.

Acknowledgement

I reserve special thanks for my wife, Tina. Her fortitude and attention to detail made her an ideal proofreader and all around Girl Friday; her patience and wisdom also made her a sympathetic ear for unending logical arguments. I could not have done this without her.

I would also like to thank all the mentors who, at one time or another, participated in my dissertation committee:

Dr. James Neiman
Dr. Laura Pogue
Dr. David Cross
Dr. James Savard
Dr. Michael Wetmore
Dr. John Theodore

Many thanks to all.

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Chapter 1: Introduction

Global air transportation system officials rely on high-quality aircraft maintenance to provide safe, reliable aircraft (Dhillon & Liu, 2006). Errors among aircraft mechanics are of particular concern to the regulatory agencies and aviation organizations in nations participating in the transportation system. Human factors (environmental, physiological, and psychological) are widely recognized as the precursors to mechanic error, and ultimately, to maintenance related aircraft accidents (Baron, 2009; Hackworth, Holcomb, Banks, & Schroeder, 2007; Hobbs & Williamson, 2003). In spite of this general recognition, officials of different nations adopted different approaches to the problem of human factors in aviation maintenance. Officials of some nations implemented regulations mandating very specific human factors training programs for mechanics. Officials of other nations took a laissez-faire approach and only required voluntary participation in human factors programs (Hackworth et al., 2007). Current researchers into the subject have focused on surveys and reviews of human factors programs, or classification of mechanic errors and the human factors leading up to a particular error. Little research has been devoted to comparisons of effectiveness of different approaches to the problem. This dissertation research involved two nations in which officials take different approaches to the problem of maintenance human factors: the United States (U.S.) and the United Kingdom (U.K.). Officials of two regulatory agencies oversee the air transportation systems of these nations: the Civil Aviation Authority (CAA) in the U.K. and the Federal Aviation Administration (FAA) in the U.S. While the design and regulation of the two systems mirror each other in most respects, the two systems are different in how each mitigates the impact of human factors on mechanics (Hackworth et al., 2007). The U.S. FAA officials do not mandate human factors programs for mechanics while the U.K. officials of the CAA implemented rigorous regulations in 2003 to mandate human factors programs for U.K. mechanics. Although current researchers have concluded that maintenance human factors training makes air transportation safer (Baron, 2009; Hackworth et al., 2007), the current literature does not provide a quantitative causal-comparative analysis between regulated and unregulated systems to determine the effectiveness of a particular approach to the problem (Lattanzio, Patankar, & Kanki, 2008). The void in the current knowledge was addressed in the dissertation research through an ex post facto analysis of aircraft accident reports and a subsequent comparative analysis of the effect of U.S. and U.K. programs.

This introductory chapter contains the background, nature, and significance of the study as well as formal statement of the problem, purpose, research questions, and hypotheses. The chapter contains a brief description of the theoretical framework, research method, and design.

Background

The dissertation research topic is of current interest based on consumer and airline concerns regarding the safety of air travel. As air travel continues to be the preferred method for long-distance passenger travel in the U.S., studies of consumer preference indicate safety as a determining factor in the passenger's selection of an airline (Bowen, Scarpellini-Metz, & Headley, 2005; Squalli & Saad, 2006). In addition to the business advantage inherent in the consumers' perception of safety in one airline over another, the airline officials' interest in increased safety also lies in another practical financial concern: expense and delay caused by accidents may be avoided through preventative measures like maintenance human factors programs (Hackworth et al., 2007; Hobbs & Williamson, 2003). The U.S. officials' lack of human factors regulations and mandatory human factors programs may lead to increased maintenance related accident rates substantially affecting the safety of air transportation in the U.S. (Fogarty, 2004; Hackworth et al., 2007; Patankar & Ma, 2006). At the same time, U.K. human factors regulations may have decreased the overall U.K. mechanic error rate, thus improving safety in the U.K. (Majumdar, Mak, Lettington, & Nadler, 2009).

Research on the effects of similar regulation was conducted in an analysis of French Air Force accident records; researchers concluded that regulation had some impact on accident rates, but cautioned that the results may not be transferable to a nonmilitary culture in which leaders cannot enforce strict discipline on the workforce (Aslanides, Valot, Nyssen, & Amalberti, 2007). Baron (2009) and Hackworth et al. (2007) also concluded that human factors programs were essential in reducing the effects of human factors and maintenance related accident rates.

In an analysis of helicopter operations, Majumdar et al. (2009) found that the officials in the U.K. and New Zealand had different maintenance related accident rates (13% and 6%, respectively). Officials in both nations operated under similar human factors regulation; thus, the findings of Majumdar et al. (2009) seem to contradict the postulate that regulations will reduce accidents (Hackworth et al., 2007).

Problem Statement

The problem is that the U.S. maintenance related accident rate is higher than the U.K. maintenance related accident rate (Aslanides et al., 2007; Hackworth et al., 2007;

Majumdar et al., 2009). Hackworth et al. (2007) noted the problem of the higher U.S. accident rate in their study of international maintenance human factors programs. Aslanides et al. (2007) and Majumdar et al. (2009) also noted that human factors related accidents represented a threat to aviation safety. Fogarty (2004) echoed these concerns and described maintenance human factors training as a key component of improved safety performance.

Since 2003, an estimated 300 fatal aircraft accidents have resulted from aviation maintenance error in the (Bureau of Transportation Statistics, 2009; Hackworth et al., 2007). The officials of the CAA, while promulgating human factors training and management programs, reported a 6% accident rate in the same period (Civil Aviation Authority [CAA], 2009). Were the U.S. officials to achieve a 6% maintenance related accident rate, fatal accidents since 2003 would have been reduced to 120. In addition to the human cost, the FAA (2005) reported that mechanic error cost airlines officials $10 billion in delays and damaged aircraft.

The cost in lives, damage, and delay is balanced by the costs of implementing a possibly ineffective human factors regulation. Based on Bureau of Labor (BLS) statistics, implementation of U.K. style regulation across the U.S. airline industry would cost approximately $100 million (Bureau of Labor Statistics [BLS], 2010). Airlines are among the most fragile industries in an economy and are consequently resistant to expensive, unproven safety innovations (Bowen et al., 2005). This resistance is based on the lack of evidence concerning the effect of human factors regulation and highlights the need for the dissertation study (Franco, 2008).

Purpose

The purpose of this quantitative study was to explore the postulate (Baron, 2009; Hackworth et al., 2007; Hobbs & Williamson, 2003) that human factors regulation will reduce maintenance related accidents by analyzing and comparing changes in U.S. and U.K. accident rates to detect and evaluate the effect of regulations. The relationship between the construct of human factors regulation and accident rates was explored by operationalizing the concept of the absence or presence of regulation into the time period (before or after regulation was implemented) or the jurisdiction (U.S. or U.K.) of the accident. No human participants were involved in the study. Instead, an analysis of U.S. and U.K. accident records was used to realize the research purpose. To achieve an acceptable power level (Faul, Erdfelder, Buchner, & Lang, 2009), a sample of 138 reports were taken from each nation's accident records during each period. The reports were analyzed using the Boeing Maintenance Error Decision Aid (MEDA) to determine maintenance related accident rates for both nations. A chi-square analysis of U.K. rates before and after the 2003 implementation of human factors regulation was used to detect and evaluate changes in accident rates. To triangulate the results of the U.K. analysis, a second chi-square analysis was performed to compare 2003-2008 U.K accident rates to U.S. accident rates. Due to the ex post facto nature of the research, two confounding variables were identified. The two confounding variables are as follows:

1. Knowledge of human factors may exist in periods and locations where the regulation is not in force, which may result in cross-contamination of comparison groups.

2. Cultural differences between comparison-groups may attenuate or obviate the effect of a regulation in a particular culture.

Theoretical Framework

Institutionalism was used to provide the theoretical framework for the dissertation study. Institutional theorists posited that organizational leaders must adapt to the regulations and customs of the institutional ecology within which they reside or face extinction within the institution (Argote & Greve, 2007; Kordel, 2008). As remaining organizational leaders adapt and avoid extinction, institutional ecology and organizations evolve toward an internally or externally directed goal (de Jonge, 2005; King, Felin, & Whetten, 2010). In the case of human factors regulations, an external evolutionary force in the form of an aviation regulator implements regulations to create a new, safer institutional ecology in aviation. If the postulate of Hackworth et al. (2007) is valid, the regulator's power to revoke licenses and impose fines should drive organizational leaders in the institution toward increased safety; evidence of this new ecology should be detected in a commensurate decrease in accidents (Kordel, 2008; Poirot, 2008). Ockree and Martin (2009) pointed out that regulation often has unintended consequences: Rather than driving the desired change in organizational leaders within the institution, regulation may drive organizational leaders out of the institution.

Oliver (1991) described a form of institutionalism that was used to add an organizational and evolutionary behavioral aspect to the old version of institutionalism proponents' strict analysis of the behavior of individuals. Although most authors agreed that institutional pressure to conform existed and had an effect on the form and behavior of an organizational leaders, few had specified exactly how the process worked and relied on normative institutionalism (Oliver, 1991). The proponents of normative institutionalism proposed that leaders of an organization recognize the benefits of cooperation and will conform to the rules and traditions of the society without coercion (Argote & Greve, 2007). Opponents of normative institutionalism cautioned that leaders all organizations would not react in the same fashion to identical environmental stimuli (regulation) and recommended measuring some form of residual evidence (records) to confirm an effect (King et al., 2010; Ockree & Martin, 2009).

Although the research questions are used to reference changes in accident rates and used to link those changes to the imposition of regulations on leaders of organizations, the research was designed around the concepts found in institutional theory. While institutional theory is used to provide a predictor of organizational behavior, the impact of current research in human factors links the higher-level theory of institutional behavior to the more pedestrian concept of reducing accident rates. In this dissertation study, the synthesis of institutional theory and human factors research is intended to provide rationale for the officials of a regulatory agency of the expectation of change in an organization based upon implementation of a new human factors regulation to suppress maintenance related accidents.

Research Questions

Since Hackworth et al. (2007) and Shappell, Detwiler, Holcomb, Hackworth, Boquet, and Wiegmann (2007) agreed that the use of maintenance human factors programs would reduce the frequency of maintenance related accidents, did the U.K. maintenance related accident rate change after the CAA officials implemented human factors regulations? What happened in the U.S. (absent similar regulations) during the same period? To address these questions, two formal research questions were developed.

Q1. To what extent does a statistically significant difference exist between the U.K. maintenance accident rate before (1995-2000) and after (2003-2008) the implementation of human factors regulations?

Q2. To what extent does a statistically significant difference exist between U.S. and U.K. maintenance related accident rates during the period (2003-2008) that U.K. regulations were in force?

Hypotheses

$H1_0$. No statistically significant difference exists between the U.K. maintenance related accident rates in the specified periods.

$H1_a$. A statistically significant difference exists between the U.K. maintenance related accident rates in the specified periods.

$H2_0$. No statistically significant difference exists between U.K. and U.S. maintenance related accident rates in the specified period.

$H2_a$. A statistically significant difference exists between U.K. and U.S. maintenance related accident rates in the specified period.

Nature of the Study

The first step in the dissertation research accessed U.K. and U.S. accident databases and sampled the specified periods for each country. In anticipation of a possibly small effect size, samples were relatively large: 138 cases (accident records) were taken from each period in each country to achieve acceptable power levels. Each case was evaluated to classify the record as a maintenance related or nonmaintenance related accident. The evaluation was based on a strict content analysis of the cause of each accident; cases were only classified as maintenance related if the causes meet the taxonomic criteria specified in Chapter 3. This taxonomic rigor was used to mitigate subjective interpretation (Duriau, Reger, & Pfarrer, 2007). The samples were analyzed to determine the accident frequency in each period in each country. The accident frequencies were compared through cross tabulation and chi-square analysis of maintenance related accident frequencies in the samples and tested to detect significant differences between U.K. periods (before and after regulations were implemented) as well as between the U.K. (regulation) and U.S. (no regulation).

Significance of the Study

The significance of the study is in the importance of reliable aircraft and maintenance processes to air transportation system and the flying public. In February 2009, 50,000 passengers boarded aircraft and flew 53 million revenue passenger miles (Bureau of Transportation Statistics, 2009). Travelers in the U.S. because of the size of the country and lack of a significant passenger rail system are heavily dependent on the air transportation system (Hummels, 2007). The users of the system are dependent on a network of aviation maintenance organization personnel to inspect and maintain the aircraft; the objective of the officials of these organizations is the error-free maintenance of safe, accident-free aircraft (Hackworth et al., 2007; Lu, Wetmore, & Przetak, 2006). Human factors regulation and training in aircraft maintenance organizations is intended to promote this objective by reducing the frequency of maintenance related aircraft accidents (Hackworth et al., 2007).

In addition to the safety-related significance, the significance of the dissertation study also includes a business component. Although the difference in the U.S. and U.K. maintenance related accident rate may represent an unnecessary cost to U.S. airlines and the flying public, costs for U.S. maintenance organization officials implementing human factors regulations in a struggling economy should be thoroughly investigated prior to implementation (Franco, 2008). Franco noted that 63% of industry respondents felt increased regulation would increase maintenance overhead costs. However, in justifying at least voluntary implementation of human factors programs, Dhillon and Liu (2006) estimated U.S. airline officials lose $5 billion annually in aircraft damages caused by human error during aircraft towing operations conducted by maintenance personnel. As a further financial incentive for implementation of human factors programs, the aviation industry officials may benefit from reduced negative effects on the business function arising from intense media attention often drawn to aircraft accidents, regardless of cause (Hackworth et al., 2007; Squalli & Saad, 2006).

The dissertation study was used to fill the void in available knowledge concerning the effect of human factors regulations on aircraft maintenance as predicted by institutional theory. The study was also used to provide statistical evidence of the effect of human factors regulation to enable officials to make data driven decisions rather than opinion driven decisions to implement such regulations.

Definitions

Accident. Title 49 (Transportation) of the Code of Federal Regulations (CFR) defined an accident as an event associated with the operation of an aircraft in which major structural damage to the aircraft, major injury, or fatality occurs between embarkation and debarkation (Transportation, 2010). In the dissertation study, the definition of accident included other reported incidents of damage to aircraft defined by the CFR as events other than accidents that could affect the safe operation of an aircraft (Transportation, 2010).

Human factors. Human factors are human-centered physical, psychological, or social properties and the interaction with machine-, organization-, or environment-centered systems. Human factor programs are used to address the interaction with methods to enhance efficient interaction while mitigating the negative effects of unfavorable interactions (Karwowski, 2006).

Maintenance. The Federal Aviation Regulation (FAR) Part 1 defined maintenance as inspection, overhaul, repair, preservation, and the replacement of parts (Aeronautics and Space, 2010).

Maintenance error. The Boeing Maintenance Error Decision Aid (MEDA) defined maintenance error as the intentional and unintentional deviation from standards and procedures (Rankin, Hibit, Allen, & Sargent, 2000). Although error often is used to imply only unintentional deviation from authorized procedures, both intentional violations and unintentional deviations are included in this definition of error.

Maintenance organization. The term, maintenance organization, includes all organizations in which personnel are engaged in inspection, maintenance, preventive maintenance, modification, alteration, repair, overhaul, ground handling, or servicing of aircraft, aircraft systems, or components. This definition combines the U.S. FAR 145 concepts of repair station and aircraft operator maintenance since personnel in both organizations have the capacity to generate maintenance error and contribute to a maintenance related accident rate. The definition also conforms to the U.K. JAR 145 specification of personnel requiring human factors training (Aeronautics and Space, 2010; CAA, 2004).

Maintenance personnel. The term maintenance personnel include the entire class of aircraft mechanic, helper, worker, and servicer labor. Subject personnel might be involved in inspection, repair, overhaul, servicing, and marshalling or aircraft ground-handling activities. Maintenance personnel also include support staff (administrative personnel, schedulers, planners, supervisors, and managers) whose duties include decision-making, analysis or record keeping during planning or execution of maintenance. The definition involves the MEDA concept of including overhead staff, their actions, and their decisions as possible contributing factors in maintenance errors (Aeronautics and Space, 2010).

Maintenance related accident. Maintenance related accidents are accidents and incidents resulting from maintenance error (Rankin et al. 2000). In this study, maintenance related accident reports must include at least one of the six maintenance error categories listed in the Boeing MEDA Section III.

Maintenance related accident rate. The ratio of maintenance related accidents to total accidents during a specified period.

Summary

The problem of maintenance related aircraft accidents in the absence of human factors regulation was addressed in the dissertation research. The research purpose to explore the effect of human factors regulation was achieved by developing and executing a quantitative ex post facto comparison of U.K. and U.S. maintenance related accident rate performances between pre- and post- regulation periods and between the nations of the U.K. and the U.S. Although the effect of regulation on accident rates was investigated, the research was illuminated by institutional theories of organizational behavior. From this theoretical perspective, the research was focused on the ability of regulations to alter institutional and organizational behavior. Within the framework, the research questions were answered using the collection, categorization, and calculation of accident rates from accident records for subsequent comparison and analysis. The analysis was expected to detect significant changes in the accident rate performance of U.K. maintenance organizations that may be related to the implementation of human factors regulation of the U.K. aircraft maintenance institution. The analysis was also expected to detect significant differences between U.K. and U.S. maintenance organizations in terms of maintenance related accident performance.

Chapter 2: Literature Review

In addressing the research purpose of exploring, analyzing, and evaluating the effect of maintenance human factors regulation on an aviation system's maintenance related accident rate, the literature review is focused primarily on scholarly references and national-level regulatory agency reports. Although the logical support for the dissertation study is found in a series of scholarly reports on human factors, the central theme of the literature is regulation reducing accident rates and requires a review of the regulatory positions of the governments involved in the study. The literature review consequently includes a review of U.K. and U.S. government documents related to the research. In addition to this regulatory context, the business context of the problem is provided using a review of scholarly literature in the areas of economic and finance. Finally, a review of the scholarly literature in the field of institutionalism was used to provide a theoretical context for the dissertation research.

Historical Context

Both the U.S. and U.K. have had a similar regulatory development processes since the inception of aviation in the early 19th century. Both nations developed regulations to first support national airmail programs and quickly realized the benefits of standardized safety regulations in terms of more efficient, accident-free operations. In the 1920s, insurance company officials typically conducted accident investigations. In these investigations, officials began to cite pilot human factors (fatigue, cold, etc.) as causes in some accidents. Insurance company officials forced leaders of early airlines to implement regulations to deal with these problems or face higher premiums; implementation decreased accident rates dramatically among early airlines (Wells &

Rodrigues, 2003). Although no national regulations existed in neither country, both the U.S. and U.K. airmail operation officials implemented regulations based on insurance company officials' requirements with equally beneficial results. By the 1920s, the need for some kind of national regulation was created because of the existence of numerous airlines in both countries. From the 1920s to the 1940s, the U.S. and U.K. officials developed along separate, but more-or-less parallel regulatory paths. Based on the onset of global air transportation after World War II, the U.S. (displacing the British Empire as a world power) aviation leaders took the lead in international aviation matters. Western European, Canadian, and Australian regulators based internal regulations on those of the U.S. This American hegemony ended in the 1990s as the U.K. officials joined the European Union in a series of aviation agreements and followed the European Aviation Safety Authority (EASA). While U.K. aviation regulations remained intact, the officials of European regulations in the 21st century required implementation of additional human factors programs for maintenance personnel by 2003. Since that time, the U.S. and U.K. officials have operated with significantly different maintenance human factors regulations (Wells & Rodrigues, 2003).

Beginnings of maintenance human factors research. Throughout the history of aviation, human factors research has been used to influence aircraft design, aviation organizations, and the regulation of pilots. Wells and Rodrigues (2003) noted that in the early days of aviation, mechanical failure accounted for 80% of aircraft accidents while the remaining 20% were the result of human error; however, by the 1980s human error accounted for 80% of accidents. The reversal was a result of improving technology and enhanced aircraft reliability; thus, shifting the focus of aviation safety officials to human error. Mechanics were seldom considered because pilot error quickly became the accepted cause of most accidents (Taylor & Pantankar, 2001). Aviation regulatory agency officials thus focused enforcement efforts exclusively on the pilot workforce in the U.S. and U.K. (Edkins, 2002). Unfortunately, by the 1990s, several high-profile lapses in mechanic judgment drew attention to the regulation of human factors in the mechanic workforce.

In 1988, an Aloha Airlines Boeing 737 suffered a spectacular structural failure when the fuselage structure surrounding the passenger compartment came off the aircraft in flight. Mechanics had repeatedly failed to detect progressive cracking of the structure. Although pilots were able to land the aircraft, the notoriety of the incident caused it to be included in almost all research into human factors as an example of maintenance errors. The Aloha incident was followed in 1991 by an EMB-120 crash at Eagle Lake, Texas after mechanics released the aircraft for flight with incomplete maintenance. Mechanics had disassembled a portion of the tail of the aircraft and failed to reassemble that portion before allowing the aircraft to be flown. The pilots were able to make a successful flight from Houston to Eagle Lake. On the return route, loaded with passengers headed for connecting flights in Houston, the aircraft disintegrated in flight. In 1995, an Atlantic Southeast Airlines EMB-120 crashed after mechanics repeatedly failed to detect advancing corrosion damage around the connecting ring of a propeller blade. Thirty-one minutes after departure, a propeller blade separated from the engine. The crew attempted a forced landing, but crashed.

The notoriety of the Aloha incident created a dramatic paradigm shift in aviation safety. Pictures of passengers still in their seats exposed by the missing fuselage structure were far more potent images of a maintenance related event than the barely recognizable remains of smoking debris at the typical accident site shown in a few seconds on the evening news. While human factors regulations were already in place for pilots, the paradigm shift was used to focus greater attention on the subject for aircraft mechanics. In the 1990s, researchers expanded their studies into how mechanics make mistakes in an attempt to answer these questions on why they were performing maintenance incorrectly or failing to recognize the need for maintenance through poorly done inspections.

Early researchers into maintenance human factors chose high profile, catastrophic events to show the dangers posed by aircraft maintenance in the absence of human factors programs. While the researchers examined each case in detail and pointed out errors for other maintainers to avoid, researchers were generally unable to demonstrate the quantitative extent of the problem in terms of maintenance related accident rate or generate trend analyses to predict future rates. As air travel increased by 187% throughout the 1990s, maintenance related accidents increased commensurately (Fogarty, 2004). Pointing out the consequences of maintenance error no longer sufficed as researchers recognized the need for more rigorous approaches to the problem.

Turning from reviews of high profile accidents, other researchers focused on classifying maintenance related accidents to evaluate the most frequent type of maintenance error to develop a focus for corrective measures (Aslanides et al., 2007; Fogarty, 2004; Majumdar et al., 2009). Still other researchers focused on developing trends from using the ASRS database of self-reported (by the mechanic) maintenance errors (Lattanzio et al., 2008; Patankar, 2003). Until 2003, researchers hinted at the benefits of human factors programs for aircraft mechanics, but were unable to provide evidence to support it because no organizational leaders had implemented such a program on a large scale. After an initial surge in the 1990s, interest in maintenance human factors quickly dissipated as investigative literature into the problem was reduced dramatically after 2001, and became nearly nonexistent after 2003 (Dhillon & Liu, 2006).

Review of Human Factors Studies

As the workload and accident rate continued to climb during the 1990s, the aviation industry officials responded by applying Maintenance Resource Management (MRM) programs to offset the perceived effects of human factors on mechanics (Taylor & Patankar, 2001). MRM programs were maintenance versions of Crew Resource Management, a human factors program already implemented for pilots (Taylor & Patankar, 2001). Taylor and Patankar studied changes in accident rates over four generations of MRM programs. As a voluntary behavior based program, Taylor and Patankar assessed the effect of MRM through case studies of individual aviation organizations. The case studies included survey and interview techniques to determine attitude changes among the target audience (mechanics). Taylor and Patankar found that positive effects of each generation of training were not lasting; mechanics quickly reverted to attitudes and behaviors of the pretraining period. While training was used to provide mechanics with the tools for managing error-scenarios, continuous use of the tools was difficult to enforce. Management member attitudes that the training was an unnecessary expense especially during the difficult financial environment of aviation in the 1990s exacerbated the failure of training to have a lasting impact on mechanics (Taylor & Patankar, 2001).

Prior to the decline of maintenance human factors studies in 2003, researchers concentrated on linking human factor causes to the actual maintenance error. Hobbs and Williamson (2003) relied on a survey of 4,500 Australian aircraft mechanics to establish a relationship between error and causal factors as preconditions for the error. In addition to questions about the participants' workplace, participants were asked to report on a critical maintenance error in their workplace as either participants or witnesses. Participants returned approximately 1400 surveys, containing 619 reports of critical errors. Errors were classified as follows:

- Perceptual (lighting or viewing angle prevented successful inspection)
- Memory (failing to perform an assigned action)
- Slip (performing the wrong action or failing to perform action correctly)
- Rule-based/violation (did not follow instruction)
- Lack of knowledge (training and certification)
- Mischance

Contributing factors were resolved into human factor categories as follows:

- Fatigue (lack of, or disrupted sleep; excessive work hours)
- Time-pressure (deadlines)
- Coordination (separate mechanics performing related tasks out of sequence)
- Training (mechanic not certified on task)
- Supervision (improper decision from supervision)
- Prior deviation (task performed incorrectly at an earlier time)
- Procedure (unclear or nonexistent directions)
- Equipment (wrong or substandard equipment)

- Environmental (cold, heat, light, etc.)
- Physiological (illness)

Hobbs and Williamson (2003) cross-tabulated errors and contributing factors and used a chi-square analysis to find significant relationships between individual contributing factors and errors. The chi-square analysis showed that each contributing human factor was associated with a specific error-type and that the increase of a factor did not result in a general increase of all errors. For example, events involving incomplete installation of a component were associated with the memory error-types and memory lapses were associated with human factors of pressure and fatigue. Hobbs and Williamson admitted they focused exclusively on reports of maintenance failure and that without reports of successful maintenance actions, the extent of the problem was not defined in terms of a maintenance error rate. Hobbs and Williamson concluded that human factors should be a key target of intervention and called for future tests of association between human factors and outcomes using other aviation databases.

By 2005, an increasing number of maintenance related accidents resulted in a renewed interest in maintenance human factors (Lawrence & Gill, 2007). In a review of 189 National Transportation Safety Board (NTSB) reported accidents involving commercial carriers between 1994 and 2004, Lu et al. (2006) noted 36% of accidents were the result of ground crew or maintenance error. As part of the revived interest, Hackworth et al. (2007) conducted an international opinion-survey of maintenance organization personnel (mechanics, engineers, management, etc.) and concluded that human factors programs would definitely enhance safety and efficiency in maintenance organizations. In the report conclusion, Hackworth et al. (2007) stated categorically, "flight safety and worker safety are the primary reasons to have such programs. HF [human factors] programs reduce cost and foster continuing safety and control of human error in maintenance" (p. 9). Hackworth et al. distributed the survey to participants in 54 countries including the U.S. and U.K. The 414 participants (65% response rate) were categorized by the regulatory framework in force at their location: Civil Aviation Safety Authority (Australia), EASA, Transport Canada, FAA, or Other National Aviation Authority. On a question concerning the existence of human factors programs at the participant's organization, participants from FAA-regulated organizations had the lowest figure. Hackworth et al. (2007) noted

> Because HF courses are not a regulatory requirement in the U.S., it was not surprising to find the largest percentage where no course existed was from companies that modeled the FAA. Obviously, this suggests that regulations are a reliable means of ensuring the presence of an HF training program. (p. 8)

Although Hackworth et al. seemed to establish the importance of regulation to ensure an organization's leaders had a human factors program for maintenance, the researchers did not attempt to establish the effectiveness of such a program.

While the aviation industry was just beginning to readdress human factors in maintenance, research into the effects of human factors on aircrew had already linked human factors to human error and attendant accident rates. Shappell et al. (2007) reviewed and classified causal and contributory factors in 1,021 accident records using the U.S. Navy Human Factors Analysis and Classification System (HFACS) to identify human factor issues in the reports. Shappell et al. classified errors as skill based, decision errors, or intentional violations of rules. Focusing on skill and decision errors, the researchers found that 70% of accidents arose from these errors and linked 24% of the errors to human factors precursors. Shappell et al. voiced the prevailing opinion in the industry and noted that, "While some of the findings may come as no surprise, they do provide data where often only opinion existed" (p. 17). Where the investigation of maintenance human factors had only established a consensus, researchers into aircrew human factors had progressed to examination of accident records with Shappell et al.

In a research effort very similar to that of the dissertation study's pretest-posttest format (Q1), Aslanides et al. (2007) investigated the effect of a 1993 human factors training plan implemented in the French air force by reviewing accident records before (1992-1993) and after (1998-2002) the regulation went into effect. The training plan was created to improve accident investigators' awareness of human factors as accident precursors. Aslanides et al. selected 35 records from each period and performed content analysis of phraseology used by accident investigators to determine the impact of the training. Although the researcher did not develop accident rates in each period, the concept of analyzing accident records before and after an event to establish a causal link between regulatory intervention and an effect detectable in the records was illustrated.

The dissertation study's comparison of two countries (Q2) was presented in a causal comparative analysis of U.K. and New Zealand helicopter accidents (Majumdar et al., 2009). Majumdar et al. collected 566 U.K. accident reports from 1986 to 2005, and 230 New Zealand accident reports from 1996 to 2006, cataloged each accident with descriptive data and presented the data in several groupings, including type of aircraft, and phase of flight. When accidents were grouped by accident causal factors, reports were categorized as: (a) failure of a properly maintained aircraft, (b) maintenance-related,

(c) pilot error or (d) mixed failure, based on a content analysis of causes and contributing factors found in the accident reports. Although U.K. and New Zealand aviation organizational leaders operate under identical human factors regulation (modeled on EASA JAR 145), the U.K. maintenance-related accident rate was 13% while New Zealand organizations had a much lower 4% maintenance-related accident rate (Majumdar et al., 2009). Experts in neither nation experienced a significant change in the frequency of maintenance-related accidents during the period of the study.

In parallel with research measuring accident rates, some researchers relied on self-reported errors from mechanics from other sources. Experts collected reports and entered information into databases including the National Aeronautics and Space Administration's (NASA) Aviation Safety Reporting System (ASRS). Like opinion surveys, these voluntary reports submitted to NASA were completed based on the willingness of the mechanic to report on the mechanic's own error. Lattanzio et al. (2008) collected 1,049 ASRS reports of maintenance error from 1998 to 2002 with the objective of classifying errors as an aid to targeting intervention. Lattanzio et al. noted the results were similar to previous descriptive and classification analyses, but were important in demonstrating the persistence of maintenance error in the face of interventions described by Taylor and Patankar (2001).

Although authors of recent surveys of maintenance personnel attitudes concluded that human factors programs for maintenance personnel would improve safety, Edkins (2002) and Hobbs and Williamson (2003) criticized reliance on opinion and attitude. Such audiences tend to seek out the "correct" answer with the participant answering in the manner he or she believes the interviewer or society-at-large wants or expects to hear, regardless of the participant's actual opinion. Lavrakas (2008) also criticized survey research in situations characterized by rigorous enforcement of regulations and tight controls on entry into a profession, such as aviation maintenance. Lavrakas felt that in the circumstance described participants might ascertain the interviewer's purpose and attempt to construct their answers to suit that purpose. Lavrakas described the phenomenon as the effect of social desirability and noted participants involved with surveys or interview questions often want to present themselves or their organization in the best possible light. Survey research on future implementation of a safety intervention, such as human factors training in labor and management, is often a survey of a more or less uninformed opinion (Lavrakas, 2008).

Due to disagreement about definitions of maintenance-related accidents, existing literature indicates a wide range of estimates concerning the effects of human factors applications on the safety performance of aircraft maintenance organizations (Dhillon & Liu, 2006; Edkins, 2002). When some researchers provided no evidence of how they arrived at their maintenance-related accident rate, the problem was exacerbated. Other researchers relied on older (1995 and earlier) estimates of the maintenance-related accident rate (Hackworth et al., 2007). When methods were carefully recorded, experts from different organizations used different reporting systems, different sampling methods, or different criteria to collect and analyze accident data, consequently arriving at different conclusions. Dhillon and Liu (2006) noted that published estimates of maintenance-related accident rates ranged from 3% to 40%, covered different periods, and used different methods to classify accidents as maintenance related. Descriptive statistics found in existing research are unsuitable for direct comparison between studies.

Human factors in other transportation modes. Far from being limited to the aviation industry, the problems associated with human factors have been found across the spectrum of transportation modes. Human error is a concern in any complex undertaking, especially in forms of transportation in which little input from operators during normal operation is required (Baysari, McIntosh, & Wilson, 2008). For instance, the Federal Railroad Authority officials require engines to be equipped with an alert system to ensure drivers stay alert during long hours on duty monitoring the progress of the vehicle rather than actively controlling the vehicle. Beyond the concerns of operator problems, railway human factors researchers have also noted the issue among railway mechanics, referenced aviation maintenance research, and used the HFACS for a directed content analysis of railway accident records (Reinach & Viale, 2006). In their investigation of six railway accidents, Reinach and Viale tested a railroad-specific version of the aviation-oriented HFACS: HFACS-RR. The railway researchers specifically noted the mechanic's error as building the later accident into the machine of the railway system. Human factors issues of fatigue, organization, supervision, schedules, and pressure could cause conditions conducive to mechanic error, which could cause or exacerbate the conditions that initiate operator error and ultimately, an accident (Baysari et al., 2008).

Like the railroad industry, maritime transportation officials are also affected by uncontrolled human factors. Despite technological improvements in navigation and automation systems, shipping accidents have increased and affected safety and the environment negatively (Celik & Cebi, 2008). Similar to railroad researchers, maritime accident researchers used the concept of content analysis of accident reports to develop human factors-related accident frequencies in an effort to identify trends in their own industry. Specifically, Celik and Cebi used a case study to support modification of the U.S. Navy's HFACS for maritime investigation and research. Celik and Cebi identified human factors issues at several levels of the organization in an original application of HFACS, and recommended continued use of the HFACS as an investigative tool.

Human factors research in other industries. Just as human factors in transportation are not limited to the aviation industry, neither are human factors problems limited to the transportation industry. Hobbs and Williamson's (2003) linked human factors to human error and subsequent accident events; although conducted in an aviation maintenance setting, their research is applicable to all industries. To avoid often - catastrophic consequences, management, engineers, and workers in the construction industry must consider the impact of human error on safety (Garrett & Teizer, 2009). Citing the 1981 Kansas City Skywalk collapse and the Texas City refinery explosion in 2005, Garrett and Teizer stated that the use of the Root Cause Analysis System (RCAS), traditionally employed in the investigation of construction error, failed to address human factors. Foregoing the traditional RCAS, the researchers applied HFACS to cases of construction accidents and compared the results to the original root cause analysis. In this secondary analysis, unaddressed organizational precursors not identified in the original analysis were detected. These human factors precursors, common throughout the construction industry, were awaiting trigger events to initiate another accident. Like much of the aviation literature in the review, the authors noted that members of the construction industry were major contributors to the economies of many countries; errors and subsequent structural failures during or after construction were negative effects that could be mitigated by human factors programs. In response, Garrett and Teizer proposed human factors awareness training for members of the construction industry to limit the economic impact of construction-related accidents.

Questions concerning human factors and the prevention of human error exist in industries other than transportation and construction. Perhaps the most insidious of these is the entertainment industry, specifically amusement rides. In a content analysis of media reports on amusement park accidents, Woodcock (2008) referred to statistics from a 2004 Consumer Product Safety Commission's report of 6,400 injuries involving travelling carnival rides and fixed-site amusement park rides. In 2004, four carnival fatalities and one amusement park fatality were reported. Woodcock demonstrated that investigators into accidents stopped at the first human error encountered and failed to search for the root cause of the error. Woodcock found that human factor root causes were not investigated and, consequently, there were no programs developed or used to mitigate the effects of poor human factors practices in the amusement industry. Although Woodcock's (2008) study was limited by the subjectivity of the journalists producing the media reports, Woodcock called for increased human factors awareness in the amusement industry, among journalists, and the public. The researcher concluded that the amusement industry officials need fixed human factors criteria and specifically referred to the MEDA, HFACS, and the HFACS railroad variation developed by Reinach and Viale (2006).

Fatigue research. In existing aviation human factors literature, fatigue was a recurring factor in several research reports (Hackworth et al., 2007; Hobbs & Williamson, 2003; Lu et al., 2006); authors described fatigue as a common precursor in maintenance related incidents. Fatigue is widely recognized as a danger and regulations limiting duty time exist for pilots, flight attendants, and air traffic controllers; however, the FAA officials provide no similar regulation for mechanics (Hawkins, 2008). Hawkins' research into the problem of long duty hours for aircraft mechanics indicated that 83% of mechanics experience fatigue on a regular basis and 70% of mechanics were pressured to work while fatigued. The research was based on a survey of 450 mechanics and NTSB accident reports and Hawkins concluded that mechanics were as susceptible as pilots, flight attendants, and controllers to fatigue-related error (Hawkins). Further, physiological researchers into human factors focused on sleep disruption (changing the waking-sleeping cycle) or sleep deprivation and the attendant degradation of performance; other factors were believed to impact performance included alcohol, prescription drugs, and over-the-counter medications were reviewed (Purnell, Feyer, & Herbison, 2002).

Researchers of human-centered research efforts subjected study participants to sleep deprivation and sleep disruption and observed the effects on cognitive and mechanical task performance by study participants compared to control group members' performance of the same tasks. Performances by members of experimental groups' performances were degraded to a level significantly lower that of those of members of the control group. Researchers determined that sleep disruptions or deprivations were as deleterious to human performance as alcohol consumption (Linch & Lee, 2008). According to Linch and Lee, 16 hours of continuous wakefulness were equivalent to a blood-alcohol level of .05. When the subject was awake for 20 hours, cognitive and fine motor skill performance had deteriorated to a level equivalent to a blood alcohol content of .10. For reference, officials in some states in the U.S. have lowered the limit for intoxication and impaired operation of a motor vehicle to .08 blood-alcohol concentration (Dee, 2001).

Referring to the results of these experiments, members of the National Transportation Safety Board [NTSB] (2010) noted that the work and management environment of aircraft mechanics were especially prone to disruption of normal circadian rhythms. Specifically, the NTSB officials cited rapidly changing flying schedules as driving equally fluid schedules in the maintenance hangar and added management members' penchant for high overtime requirements to the problem of mechanics' sleep disruption and deprivation. Drury, Saran, and Schultz (2004) illustrated these observations and conclusions with case studies selected used to highlight the potentially catastrophic consequences of circadian disruption in industrial settings. Members of industrial environments, such as aircraft maintenance personnel, with highly variable work schedules are particularly prone to a fatigued workforce exhibiting degraded performance in terms of maintenance error (Hackworth et al., 2007).

In early investigations into the human factors of the maintenance environment, researchers estimated that slightly over 50% of U.S. aircraft mechanics are engaged in night-shift (graveyard or afternoon shift) operations (Purnell et al., 2002). These workers were susceptible to circadian disruption, fatigue, and micro-sleeps, which are the human brain's attempt to re-establish the day-night, awake-sleep cycle by going into sleep mode for a few seconds. Purnell et al. noted these workers might experience several micro-sleep events per shift and other micro-sleeps while awake during daylight hours away from their workplace. While the majority of micro-sleeps are innocuous (the microsleeper often appears awake, just not paying attention), when the micro-sleep occurs at a crucial juncture in an industrial operation, such as de-energizing a circuit or closing a valve, the consequences to the sleeper's safety and to coworkers can be catastrophic. In aircraft maintenance, this form of impairment raises the possibility of maintenance error with consequences beyond the immediate safety of the mechanics. Micro-sleep events in maintenance personnel who are inspecting and maintaining aircraft can present a hazard to the crew and passengers of a poorly maintained aircraft.

Although the FAA experts debate the effectiveness of regulations in mitigating the risks associated with mechanic fatigue, the U.S. Department of Defense (DOD) officials have recognized the benefits of human factors training among personnel. The DOD officials employ the sleep activity fatigue and task effectiveness model to train personnel to identify high-risk conditions for human factors-related (fatigue) accidents. In addition, the DOD officials use the fatigue analysis and scheduling tool to predict the incidence of high-risk conditions and recommends earlier interventions to mitigate those risks (Caldwell et al., 2009). Maintenance leaders in the U.S. Air Force (USAF) have long been advocates of research into the impact of human factors on its most important resource: pilots. Recognizing the importance of safe, reliable aircraft to the accomplishment of its mission, USAF officials also provide human factor regulation to aircraft mechanics in the form of duty restrictions. During routine operations, USAF aircraft maintenance personnel cannot work on aircraft for more than 12 continuous hours. Supervisors are prohibited from building schedules and plans that might require maintenance personnel to work beyond 12 hours (United States Air Force, 2006). Along the same lines as DOD and USAF, Transport Canada (the Canadian aviation regulator) leaders have recognized the danger of fatigue in aircraft mechanics and implemented a separate fatigue risk management system as part of a distinctly Canadian human factors program (Caldwell et al., 2009).

That pilots are subject to extreme human factors is a given quantity: modern aircraft can fly at oxygen-starving altitudes and perform maneuvers at G-forces sufficient to disorient, render unconscious, or kill pilots (Wells & Rodrigues, 2003). Management members can waive restrictions on a pilot's duty day to continue the mission because of operational or maintenance delays. Aircraft mechanics (at least in their routine work activities) are not subject to the same physiological extremes of oxygen deprivation or G-forces. Mechanics are instead subjected to fatigue-inducing schedule changes resulting from operations managers' decisions (i.e., flying schedule changes accelerate maintenance production) or maintenance managers' decisions (i.e., the repair did not work, try again, or the inspection showed more damage than predicted, mechanics go on overtime). Authors of research into human factors training for aircraft mechanics have focused on the effects of fatigue and subsequent errors contributing to maintenance-related accidents.

In discussing the well-known effects of fatigue on pilots, Caldwell et al. (2009) described the effect of fatigue on an individual's performance. As mechanics experience long periods of overtime and fatigue, an error-accident scenario develops and the mechanics' attention spans narrow. Inattention to perceived minor, but in reality important, information becomes increasingly common. Lapses of attention and memory failure become more frequent. Perception of reality changes as channeling (hallucinations of expected though nonexistent inputs) and lucid (waking) dreams occur.

Mechanics develop tunnel vision and hearing thus tending to tune out increasingly relevant information as their brains lose processing capacity and automatically slow to preserve some level of accuracy in decision-making. Ultimately, the brain shuts down higher-level functions to conserve any remaining energy and micro-sleep occurs. Channeling (the brain creating information that does not exist in reality) or lucid dreaming occurs to fill in gaps created by inattention, cognitive slow down, and brain shut down [the micro-sleep] (Caldwell et al., 2009). The mechanics in these circumstances completes their work after a 16-hour shift and perform a tool inventory to ensure all tools have been removed from the aircraft before flight. The fatigued mechanic's brain constructs the presence of a missing tool in the toolbox (because it has always been there before), not realizing the tool was left in the aircraft where it may damage or jam critical flight control systems during flight.

The fatigue scenario above is a pastiche of the most often-cited root causes in a human factors-related incident; human factors training program experts focus on mitigating the effects of fatigue in workers by creating organizational awareness among mechanics. The U.K. human factors regulation experts provide such training to mechanics as well as administrative and management personnel who establish and change schedules, assigning overtime and shifts as necessary to keep work on schedule (Civil Aviation Authority, 2004).

Regulatory Context

The Civil Aviation Authority (CAA) officials reinforced the conclusions found in the scholarly literature in an analysis of 3,500 error reports from the CAA Mandatory Occurrence Reporting Scheme (MORS). The MORS database was comprised of mandatory reports of aircraft accidents and incidents much like the AAIB database. Unlike the AAIB database of aircraft accidents and incidents, the MORS database also included reports of error detected before accidents could occur. The CAA reported that the implementation of human factors regulations in maintenance organizations might have had a role in the declining rate of mechanic error and subsequent maintenance-related accidents. Specifically, the agency officials noted the mechanic error rate seemed to decline from 2000 to 2005 and noted the reduction appeared to coincide with the CAA officials' implementation of human factors training programs (CAA, 2007). The CAA (2009) officials claimed a current maintenance error rate of 6% of total MORS reports, somewhat less than the 15% maintenance-related accident rate cited by the FAA officials (Hackworth et al., 2007).

The FAA officials acknowledged the importance of human factors in aviation but concluded that human factors was a complex matter involving personal responsibility; the imposition of regulations on maintenance organizations would therefore not have the desired effect of creating safer aircraft maintenance (FAA, 2007). The NTSB (2010) officials took note of this apparently self-contradictory position of the FAA officials and insisted that the FAA officials' education and awareness approach was inappropriate and the need for regulatory intervention was indicated by the research. A dichotomy exists in the CAA officials' position, who viewed maintenance human factors regulation as important, essential, and possibly effective, while FAA officials saw the programs as less effective or at least unproven in expected outcomes. The dichotomy was extended to the real air transportation system as the U.K officials adopted maintenance human factors programs while the U.S. officials did not.

In response to the conclusions of their own maintenance human factors research, the CAA officials began implementing JAR 145 in 2001 and required full implementation by January 1, 2003. In order to implement JAR 145, leaders of U.K. aviation maintenance organizations were required to develop monitoring and training programs to detect, investigate, and prevent mechanic error in aviation. Awareness and prevention training was applicable to all areas of the aviation organization: licensed mechanics, their helpers, supervisors, management, engineers, planners, and schedulers. In the implementation of JAR 145, the regulation also specified programs for reporting, investigating, determining root causes (human factor), and recording corrective actions in maintenance error to facilitate future root cause and trend analysis (Civil Aviation Authority, 2004).

Business and Financial Context

The problem of aviation safety represents a difficult financial and business topic. In spite of the inherent dangers of air travel (speed, altitude, noncrash survivable structures), each safety improvement throughout aviation history has been carefully scrutinized in terms of cost in an effort to keep air travel affordable to the public (Franco, 2008; Wells & Rodrigues, 2003). Since airline officials typically operate on a razor-thin margin of profit, with high fuel, maintenance and payroll costs, all other costs must be avoided to maintain even a minimal profit level and offer flying service to the public; costs of safety improvements are thus of great interest to the aviation industry (Squalli & Saad, 2006).

The developers of the original U.S. Civil Aeronautics Authority of the 1930s, the antecedent of the modern FAA, recognized the economic factor of the airline's existence.

The charter of the United States' early aviation regulator was developed to promote aviation through improved safety, public acceptance, and economic growth of airlines (Lu et al., 2006). At the same time, as the nascent organization officials were investigating early accidents and identifying safety improvements, each safety improvement was being weighed against the financial cost of the improvement. Officials routinely abandoned safety improvements as too expensive for the early airlines officials to adopt (Wells & Rodrigues, 2003). Even in 2010, airline officials face the same dilemma: the cost of a safety improvement, such as a new training program, or the risk of reduced enplanements on an airline perceived as unsafe by the flying consumer (Squalli & Saad, 2006).

The economic conditions of the aviation industry in the first years of the 21st century influenced researchers' efforts into maintenance human factors. A sharp decline in subject literature coincided with economic turmoil in the industry following the September 11, 2001 terrorist attacks that forced officials of many aviation organizations to abandon voluntary maintenance human factors programs (Dhillon & Liu, 2006). In the then-prevailing economic environment, the Air Transportation Association officials saw maintenance human factors as a low priority given the economic conditions and uncertain benefits of such training for maintenance personnel (Dhillon & Liu, 2006). In the midst of the debate about the effectiveness of human factors programs and recessionary economic conditions, airline officials began to experience some recovery and a renewed interest in maintenance human factors resurfaced after a 2002 through 2006 hiatus (Cheung, Ip, Lu, & Lai, 2005).

The idea that human error has a production cost beyond the cost of rework arising from human error has created renewed interest. Peterson, 576th Aerospace Maintenance and Regeneration Squadron Leader (personal communication, 18 March 2008), noted that approximately 20% of maintenance cost involves preemptive efforts by mechanics to find another mechanic's error. Without maintenance errors, there would be no operational checks required on the aircraft; every maintenance procedure would be completed correctly the first time. As it is, inspections and operational checks are essential factors in eliminating an estimated 90% of mechanic error before the errors enter into the accident chain of events.

As fatigued, distracted, or otherwise less than engaged mechanics leave uncorrected errors in their work, ground or flight crews will catch the vast majority (approximately 90%) of such errors during subsequent operational checks and inspections. Unfortunately, the remaining 10% of maintenance errors will proceed without intervention into an accident chain of events (Wong, Pitfield, Caves, & Appleyard, 2006). Even without extensive knowledge of human factors, maintenance organization officials unwittingly demonstrate the existence of human error in the tradition of second-mechanic inspections of critical tasks, quality assurance evaluations, and operational checks after system repair. Without human error, none of this would be required.

Typically, aviation safety improvements do not have financially definable returns on investment and might be viewed as less-than-necessary drains on the business function of the airline, while operations (pilots, cabin crew, airport representation) are revenue generators (Squalli & Saad, 2006; Wells & Rodrigues, 2003). Costs to train maintenance personnel in a safety improvement of unproven value as well as programs to reduce maintenance error are costs deducted from the airline's revenue. Into this milieu, the vague notions of human factors training for aircraft mechanics must be compared with all the other cost factors facing the airline officials. Even though the costs are comparatively small based on the material costs of accidents, rework, and loss of revenue, it is a difficult decision to make.

The FAA officials do not track these costs from an analytical perspective. Financially, costs are recorded by the business leaders, but the FAA officials do not collect this information with any intention of trend analysis or rolling up 10-year costs for comparison against 10 years of a training program (Squalli & Saad, 2006). Exacerbating the problem of researching the business context of human factors, the FAA officials do not track maintenance-related accidents as an independent statistic; the FAA officials do record aircraft accidents and incidents, and the information identifying the accident as maintenance related is somewhere in the record. Consequently, airline management is unlikely to have relevant information of the aviation business environment in terms of the maintenance-related accident rate or the leading causes of such accidents to inform decision making with regard to human factors training programs for mechanics (Lu et al., 2006).

The reluctance of FAA officials to impose regulations does not align with industry estimates of the cost of maintenance error borne by the airline. The Hackworth et al. (2007) study noted that 20% to 30% of in-flight engine shutdowns were due to maintenance error and cost an airline $500,000 for each occurrence. The International Air Transport Association (2004) experts found that maintenance errors were responsible for 50% of gate delays and flight cancellations; each hour of delay at the gate cost an airline $9,000 and a flight cancellation cost $66,000. The FAA (2005) officials also noted that maintenance errors during ground handling of aircraft, such as maintenance taxi, towing, and pushback from gate, cost airline officials $5 billion annually. In addition to these production costs, Squalli and Saad (2006) estimated the negative publicity of accidents cost airlines $360 million in annual revenue.

While there are no estimates on the return on investment expected from instituting a maintenance human factors program, a rough estimate can be calculated using Bureau of Labor Statistics [BLS] (2010) information. According to the BLS (2010), there are approximately 140,000 aircraft mechanics in the U.S. At a $45 per hour fully burdened labor rate, every hour of instruction time in a course on human factors would cost aviation business leaders $6 million. If instruction and scheduling changes for workers brought on by a new regulation increased airline costs by $100 million, the program officials would only need to reduce ground handling accidents (the $5 billion cost above) by 2% to achieve cost parity.

Theoretical Context

Due to the absence of formal theories in aircraft maintenance (Dhillon & Liu, 2006), a theoretical framework of institutionalism (Oliver, 1991), organizational evolution (Poirot, 2008), and rational action (de Jonge, 2005) are used to show the behavior of organizational leaders responding to regulatory changes and establish a conceptual context for the research.

Institutionalism. Proponents of institutionalism define the organization as a group of individuals assembled for an institutional purpose. Organizations exist within an institution. The institution is not composed of the individuals or the organization; instead, it is the environment of regulations, laws, and customs within which the organization operates (Oliver, 1991).

Existing institutional theory was developed from early theories of normative institutionalism. Normative institutionalism proponents proposed that institutional behaviors could be analyzed through the concepts of political or social volition; institutional leaders autonomously move toward the political or social benefit of constituent organizations. In this earlier, utopian view of institutionalism, authors focused on how leaders of organizations and institutions were believed to act or how institutional leaders should act with little measurement of what actually happened within institutions (Oliver, 1991).

Later versions of institutionalism's fundamental theory were used to describe the institution's behavior in terms of maximization similar to the concept found in economics (de Jonge, 2005; Oliver, 1991). In this concept, leaders of the aviation organization, as distinct economic entities sought to maximize the value to society of the aviation industry through safer operations; the leaders of the aviation institution maximizes value to society through progressive development of a safer air transportation system (Oliver, 1991). Institutional theory proponents thus identify aircraft maintenance (like other institutions) as a separate actor in political and economic reactions. Although organizations do not have a distinct emotional identity, the organizational leaders collectively select a particular course of action in response to an external stimulus (Argote & Greve, 2007). The institutional leaders adapt as increasing numbers of leaders in the organizations within the institution make similar decisions and take similar courses of action to respond to institutional pressure to conform (King et al., 2010). Aviation maintenance, as an institution, should move toward its goal as its organizational components respond appropriately to the stimulus of human factors regulation. The institutional leaders thus maximizes value by achieving a publicly acceptable level of safety in what is an inherently dangerous undertaking (transporting passengers through the air at hundreds of miles per hour, thousands of feet above the ground in an aluminum tube designed more for aerodynamic shape than crash-survivability).

As the broad theoretical substrate of the research, Oliver (1991) presented a general theory of institutionalism and described regulation and enforcement as essential to the institutional realization of goals. At its most basic level, the institutional relationship between regulation and the organizational leaders resembles the laws of inertia posited by physicists: an organization's leaders will continue along an inertial vector until an outside force acts on the organization to change the vector (Dobrev, Kim, & Carroll, 2003). This outside force in business could be investor pressure to increase profits with the implication that investment dollars will go elsewhere in the absence of change on the organization's part. Alternatively, the force might be new federal regulations regarding implementation of ethics training in an attempt to restore public trust in the marketplace (Sarbanes-Oxley, 2002), once again maximizing the social value of the institution. Leaders of larger, more respectable, older institutions may have sufficient inertia to resist sudden change and not respond to a regulation as expected; the regulator's efforts might have no effect, or result in unintended consequences (Ockree & Martin, 2009).

Oliver (1991) noted that institutions, like the human constituents making up the institution, are unique in the ability to visualize complex future conditions and thus continually prepare for future events. Oliver saw organizational leaders engaged goal-oriented activity in the pre-event planning stages before real evidence of reward was available. This less reactive behavior aims toward some form of future value maximization foreseen by the institution. Visualizing this future value maximization develops hypothetical information about possible outcomes and simulates planning of a future process. Unlike more reactive, evolution-oriented models of organizational behavior, the information is used to alter behavior before events occur. Proponents of institutionalism attempts to explain this feed forward behavior of institutions apart from the behavior of component organizations and individuals (King et al., 2010). Proponents of institutionalism recognize the behavioral input of unique individuals (continually engaged in feed forward analysis) but assert that the institution is studied through the aggregate behavior of the group rather than individual behavior in its motivation and goals.

Organizational evolution. Poirot (2008) examined this distinct aggregate behavior separate from the behavior of the individuals that make up the organization and observed that it acted like an organism possessed of its own independent will. While the individuals comprising the organization might be motivated by a paycheck or a promotion, the theoretical business organism was motivated by continued survival. Financially and tactically, the organism moved to hire the best it could afford, attempted to make the best decisions, and acted on internal and external information to increase its chances of economic survival. Poirot (2008) likened this behavior to the development of an organism's behaviors as observed through the lens of evolutionary theory. In evolutionary theory, changes in an organism's environment create survival pressures, forcing the organism to adapt as a species.

Oliver (1991) found that, unlike evolution in the animal kingdom, the business organization did not have to wait for transfer between generations but could redesign itself under pressure from competitors or regulators. When confronted by changes in the marketplace for example, the organization can develop a new product or a new marketing campaign for an existing product. As new regulations are implemented, the organizational leaders establish programs to ensure compliance or bribe an inspector to avoid compliance. In the same way, an organic species might develop increased speed and endurance to avoid predators through successive generations, the wider industrial institution to which the organization belongs might move toward the goal of the regulator's efforts. Much like the predator, the regulator eliminates organizations unable to adapt to the new environmental requirements of continued business and the organization's behaviors are extinguished from the evolutionary record. To counter this threat, the organization can mimic the behavior of successful organizations confronting the same threat or develop wholly new countermeasures. Oliver saw this behavior as organizational learning and described it as distinct from the learning among the individual members of the organization.

Rational action theory. According to de Jonge (2005), Oliver's (1991) learning members of the organization are rational actors, and microeconomic theory is used to predict their behavior as individual mechanics and as maintenance organizations. The behavior should move organizational leaders toward the regulatory agency's members goal of improved safety performance through regulatory compliance to protect a critical component in the organization's revenue source (operating certificates and licenses) from the regulatory agency's enforcement actions (revocation of certificates and licenses). Leaders of individual organizations might clandestinely opt to avoid the regulation by falsifying training records or bribing inspectors; as an institution, however, this synthesis of theories indicates the institution should undertake some detectable movement toward the goal of institutional behavior change (Frahm, 2007; Van de Ven & Poole, 2005). When organizational survival is threatened with certificate revocation for failure to comply with new regulations, the synthesis of these theories is used to predict the institution as a group of organizations should invest scarce resources with a bias toward achieving compliance, protect the path to revenue, and thus evolve toward a safer institution (Lamy & Fox, 1999; Poirot, 2008).

Like the dichotomy of opinion between the CAA officials' acceptance of the effect of regulation and the FAA officials' rejection of the same concept, a similar disagreement exists between institutional theorists. While Oliver (1991) and King et al. (2009) insisted on the predictive capacity of institutional theory to define probable results of a regulatory intervention, Frahm (2007) and Poirot (2008) countered that the presence of large numbers of individuals and the permutations arising in their aggregate behavior make prediction too difficult. However, these institutional researchers did not point to significant numbers of successful or failed predictions to support their respective positions (Poirot & Pavel, 2008). Poirot and Pavel criticized the reliance on metaphysical, normative discussions of public policy and called for greater reliance on empiricism and practical research into the question of institutional response to regulation.

The synthesis of institutionalism, organizational evolution, and rational actor theory was used to provide the context of the dissertation research. The context is essential for answering fundamental questions surrounding the assumptions of the research. While human factor studies indicate that the institution of aircraft maintenance should produce fewer human errors after implementing a new regulation, institutionalism proponents predict organizations will adapt to the new regulatory ecology of safer aviation. In spite of these predictions, no evidence was presented in the literature to show the actual outcome by comparing periods or areas of the absence and presence of a regulation.

Summary

Arranged chronologically, aviation human factor researchers illustrate the thematic path of research in the topic. Researchers began with case studies of high profile accidents, and then shifted their focus to maintenance errors; studies of error developed several error taxonomies and provided methods for categorizing error by taxonomic type. In subsequent research, researchers detected associations between mechanic error and human factors as a root cause. With this relationship established, further research was used to survey the opinions of maintenance personnel and establish the importance of regulations to enforce human factors programs. By 2009, researchers were studying the result of mechanic error in the form of accident rates.

Arranged topically, the review posits two important points: (a) intervention to reduce maintenance-related accidents should target the human factor root cause (Fogarty, 2004; Hobbs & Williamson, 2003); (b) human factors regulation is necessary to reduce maintenance-related accidents (Hackworth et al., 2007; Majumdar et al., 2009). The assertion of the effectiveness of human factors training for aircraft mechanics has been found throughout aviation and safety literature. This assertion is a widespread belief that has not been supported by any objective evidence. While in the literature review the need for human factors regulation was noted and the literature reviewed provided expectation of the effect of such regulation, no before-and-after analysis of accident rates in nations where regulation went into effect were provided. The review thus indicates the need for a causal-comparative analysis of the effect of human factors regulation on maintenance-related accident rates. The topical arrangement also highlighted the dichotomy of U.S. and U.K. reactions to human factors regulations for maintenance personnel as well as the dichotomy of scholarly opinion in human factors and institutional literature.

The literature review also showed the method by which the purpose of the dissertation research was achieved: six of the studies followed the dissertation research design of sampling accident records, analyzing records for maintenance error or human factor, calculating rates or frequencies, and comparing the results. Four studies included or recommended a content analysis of records and used HFACS, MEDA, or other taxonomy as the criteria for a human factors or maintenance-related accident. Three studies included a chi-square analysis to compare results of the content analysis.

The dissertation research was used to fill a gap in existing knowledge in both institutional theory and in its rendering of new aviation safety knowledge. This new knowledge was achieved by taking the next logical step beyond the literature and asking more pedestrian questions: since something should have happened, what actually did happen in the United Kingdom? (Q1) and what happened in the United States during the same period (Q2)?

Chapter 3: Research Method

The purpose of the quantitative study was to explore the postulation that human factors regulation will reduce maintenance-related accidents by evaluating changes in U.S. and U.K. accident rates. The research was designed to investigate the problem of aviation maintenance-related accidents in the presence and absence of human factors regulations for maintenance organizations. The effect of the JAR 145 was explored by comparing the frequency of maintenance-related accidents in the U.K. before and after implementation (Q1) and triangulated by comparing U.K. and U.S. accident rates (countries with and without the regulation, respectively) (Q2). The research plan was based on the example of previous analysis of accident records (Aslanides et al., 2007; Majumdar et al., 2009). The dissertation study used a similar quantitative ex post facto design to categorize commercial aircraft accident reports from both nations as maintenance-related or non-maintenance-related and compare the frequency of maintenance-related accidents during specified periods in the U.S. and U.K. Since methodological differences in the literature render current estimates of accident frequencies unsuitable for comparison (Dhillon & Liu, 2006), a single instrument, the Boeing MEDA, was used to define the maintenance-related accident and develop accident frequencies for specific periods in both nations.

As stated in Chapter 1, the problem investigated in the dissertation research was the higher U.S. maintenance-related accident rate when compared to the U.K. maintenance error rate. Two research questions were derived from this combination of problem and purpose:

Q1: To what extent does a statistically significant difference exist between the U.K. maintenance accident rate before (1995-2000) and after (2003-2008) human factors regulations were implemented? Hypotheses $H1_0$ and $H1_a$ were developed to support statistical testing to detect significant changes in the U.K. maintenance-related accident rate.

Q2: To what extent does a statistically significant difference exist between U.S. and U.K. maintenance-related accident rates during the period U.K. regulations were in force (2003-2008)? Hypotheses $H2_0$ and $H2_a$ were developed to support statistical testing to detect significant differences between U.S. and U.K. maintenance-related accident rates.

$H1_0$. No significant difference exists between the U.K. maintenance-related accident rates in the specified periods.

$H1_a$. A significant difference exists between the U.K. maintenance-related accident rates in the specified periods.

$H2_0$. No significant difference exists between U.K. and U.S. maintenance-related accident rates in the specified period.

$H2_a$. A significant difference exists between U.K. and U.S. maintenance-related accident rates in the specified period.

The remainder of this chapter will be used to provide a description of the research design, the measurement instrument employed, and the assumptions, limitations, and delimitations of the research. Although the research planned for Q1 and Q2 is identical in many respects, salient differences can be found in the data collection, processing, and analysis section; this section is subdivided into sections presenting each of these topics from the separate perspectives of Q1 and Q2.

Research Method and Design

The quantitative, ex post facto research design of Q1 proceeded in three main stages: (a) collection of samples of accident reports from the U.K. Air Accident Investigation Branch (AAIB) database during the 1995-2000 and 2003-2008 periods in question, (b) criteria-directed content analysis and classification of each report, and (c) comparative analysis of the maintenance-related accident frequency in each sample. The design took statistically viable (in terms of power and effect size) samples from AAIB accident records during 5-year periods before and after the 2001-2002 U.K. implementation period of the JAR 145 regulation. Within each sample, each report was analyzed using the Boeing MEDA as criteria in a criteria-directed content analysis. The content analysis classified each report as either maintenance related or nonmaintenance related. The classification was used to determine maintenance-related and nonmaintenance related accident frequency for each sample. A comparison of these before-and-after frequencies was expected to reveal the effects of regulation on U.K. aircraft maintenance.

In an attempt to triangulate the results of Q1, the investigation of Q2 compared the performance of U.K. (with regulation) to U.S. aviation maintenance (without regulation). Research Question 2 was addressed through an ex post facto evaluation and analysis of U.S and U.K. accident records using a procedure similar to the procedure described above for Research Question 1. Although the investigation of Q2 involved the same sampling methods, criteria directed content analysis, and techniques for evaluation of hypotheses, the hypotheses, as well as the data collected were materially different from Q1. To evaluate Q2 hypotheses of different accident frequencies between nations, statistically viable samples were taken from NTSB accident records during the 5-year period (2003-2008) after the 2003 U.K. implementation of the U.K. JAR 145 regulation. The NTSB sample was compared to the U.K. post-implementation sample taken from AAIB accident reports in Q1. The comparison was completed through cross tabulation and chi-square analysis of U.S. and U.K. accident frequencies.

In selecting a method to address the research questions, qualitative methods have been avoided because the research purpose requires a method for quantifying and comparing the performance of aviation maintenance institutions with and without human factors regulations. Unable to recreate the events recorded in accident reports, experimental research was rejected in favor of the ex post facto design.

Trochim and Donnelly (2008) stated that an ex post facto analysis, in addition to other features, held a distinct advantage in its unobtrusiveness and its consequent removal of the researcher from the actual events. The ex post facto design of the study limited the effect of the researcher's presence on the subjects as well as the subject's bias in the reporting of the event, thereby adding to the credibility of the research (Strauch, 2004). While the dissertation research contains some hallmarks of more experimental methods, records of events that have already transpired were relied upon primarily. The implementation of new regulation and the accidents are reviewed as archival information and no attempt was made to establish experimental treatment and control groups.

Strauch (2004) defined the difficulties of ex post facto accident analysis (lack of direct observation) along with the advantage of avoiding the ethical problems of subjecting human participants to the stresses of actual accident environments. Unable to recreate accidents in laboratory conditions, authors on safety management, such as Strauch (2004), Wong et al. (2006), and Netjasov and Janic (2008) thus advocated ex post facto approaches in analysis of accident investigations and reports of those investigations.

Wong et al. (2006) and Strauch (2004) recommended content analysis and classification of accident reports into categories, such as maintenance-related or non-maintenance-related for a variety of purposes including identifying trends and causes. Rourke and Anderson (2004) provided a method for quantitative content analysis of written reports using predetermined criteria to identify occurrences of words and phrases in a document and collect those occurrences into frequencies to uncover trends and characteristics of groups of documents. The concept of ex post factor content analysis of records is common among aviation researchers; Aslanides et al. (2007), Hobbs and Williamson (2003), Majumdar et al. (2009), Squalli and Saad (2006), and all relied on similar methods to establish rates, trends, and effects in their research.

Participants

No human participants were involved in the dissertation study; instead, an ex post facto content analysis of accident reports was used to form the core of the research plan. The accident reports were drawn from the AAIB database. The AAIB database was filtered for commercial aircraft accident reports in two periods: 1995 to 2000 and 2003 to 2008. These 5-year periods (1 January 1995 to 1 January 2000) were chosen as periods immediately surrounding the implementation period (2000-2003) of the U.K. regulation. Commercial air transport involves operations offering transportation services for hire to the public. Sport Aircraft, for example, FAR Part 91 general aviation aircraft in the U.S. as well as helicopter transport were excluded from this study. The aircraft categories chosen for the research were based on the maintenance operation requirements under JAR Part 145.

Samples were selected from aircraft accident records using the simple random method described by Trochim and Donnelly (2008). Once 1995 to 2000 and 2003 to 2008 research databases (compilation of all U.K.-registered commercial transport accidents in the selected period) are created, statistical sampling was performed using a commonly available spreadsheet application and its embedded sampling facility. A sample size of 138 was determined using G*Power 3.1.2 for chi-square goodness-of-fit test in contingency tables (Faul et al., 2009):

Analysis: A priori: Compute required sample size

Input: Effect size *w* = 0.25

α err prob = 0.10

Power (1-β err prob) = 0.90

Df = 1

Output: Noncentrality parameter λ = 8.6250000

Critical χ^2 = 2.7055435

Total sample size = 138

Actual power = 0.9018205

The medium (.25) effect size was chosen for this calculator based on chi-square scenarios of notional data (Oyeyemi, Adewara, Adebola, & Salau, 2010). Notional data were based on estimates of U.S. and U.K. maintenance-related accident rates noted in

Hackworth et al. (2007). Selecting a higher alpha (.10) was used to define the acceptance of the consequences of Type I error probability (improperly rejecting the true null hypothesis will support implementation of an ineffective regulation with its attendant, unnecessary economic burden). The acceptance of greater Type I error was used to reflect the desire to attenuate the effect of Type II error (improperly supporting the false null hypothesis will forego the life- and cost-saving benefits of a truly effective regulation) (Lee, 1985; Trochim & Donnelly, 2008).

For Q2, a similar sample was taken from the NTSB (U.S.) database. The NTSB data was filtered for FAR Part 121 and 135 (Air Carrier and Commuter, respectively) aircraft accident reports occurring during the 2003-2008 period. Despite the differing terminology between the two aviation transportation systems, the data filters represented the same type of commercial air transportation operations. A sample of 138 records was selected from the NTSB aircraft accident reports using the simple random method described for Q1. The resulting U.S. 2003 to 2008 sample was compared to the existing U.K. 2003 to 2008 sample.

Materials/Instruments

Each sample accident frequency was measured by content analysis of accident records using the MEDA (see Appendix A) as predetermined criteria to discriminate between maintenance-related and non-maintenance related accidents. The MEDA was chosen for the study based on industry-wide acceptance of it as a maintenance error taxonomy: the MEDA is one of the two most commonly cited maintenance error detection tools in aviation literature [the other being the U.S. Navy's HFACS-ME] (Hackworth et al., 2007). The MEDA was developed by experts at Boeing, the Air

Transportation Association, and the FAA as a standardized tool for the detection and analysis of maintenance errors (Rankin et al., 2000). MEDA procedures and forms are distributed for public use and are readily available on the FAA's Aircraft Maintenance Human Factors Web portal.

In testing the MEDA's reliability and validity, the presence or absence of regulation as an independent variable was already established in the AAIB and NTSB databases by the date of the event. Reliability and subsequent validity of measurement by content analysis was assessed by testing the coding system (the MEDA) on different databases with volunteer coders, as recommended by Rourke and Anderson (2004). Testing was focused on coding of dependent variables because independent variables in the study are relatively simple concepts of date of an accident and national registry of the aircraft. The NTSB and AAIB databases were examined to create small, handpicked U.S. and U.K. test databases. During testing, the databases were not analyzed to determine the maintenance-related accident rate in each period, the test databases were used instead to test the MEDA's capacity to discriminate between maintenance- and nonmaintenance-related accidents in the hands of coders from various backgrounds. Volunteer coders consisted of a U.S. Air Force aircraft mechanic, a supply clerk, and a truck driver.

Reliability. Hobbs and Williamson (2003) originally assessed reliability of the MEDA. During their human factors research, the Hobbs and Williamson used check-coders to determine the intercoder reliability of the MEDA. Check-coders analyzed 40 accident records to classify the type of accident. The pretest of the MEDA by Hobbs and Williamson achieved a 90% level of agreement between coders.

For the dissertation research, reliability of the measurement system was evaluated using Cohen's kappa, a coefficient of intercoder agreement. Semler (2001) presented kappa as:

$$\kappa = \frac{P_A - P_c}{1 - P_c}$$

where:

P_A = proportion of units on which raters agree, and

P_c = proportion of units for which agreement is expected by chance.

The MEDA tool was tested by volunteer coders who classified small, select samples of accident reports from NTSB and AAIB records. Conclusion sections of 10 AAIB and 10 NTSB records were chosen. Coders received a group briefing on the MEDA application (condensed from the MEDA user's guide). An analysis of the test results revealed an average kappa coefficient of .88 described by Semler as "near perfect agreement" (p. 6). This level of agreement compared favorably with the HFACS-ME, which achieved an intercoder reliability score of .85 (Schmidt, Schmorrow, & Figlock, 2000). Given the restrictions on coder-interpretation of material, Rourke and Anderson (2004) required high levels of reliability in criteria-directed content analysis. Based on Hobbs and Williamson's (2003) results, the successful comparison to Schmidt et al. (2000), and Semler's performance standards, the MEDA was accepted as a reliable instrument for this study.

Validity. Zikmund (2003) noted that content (or face) validity refers to the subjective agreement that the scale measures what it appears to measure and specifies that "clear, understandable questions" are "generally agreed to have face validity" (p. 302). Rourke and Anderson (2004) noted that validity in content analysis relies primarily on content validity because researchers using this measurement technique must strive for intercoder agreement through universally understood and rigorously defined categories. The content validity of the dissertation research was demonstrated by assessing variables in terms of binary concepts of date, registration, absence or presence, and maintenance or non-maintenance in categories on a dichotomous, nominal scale. For example, values for independent variables were developed through a series of clear, understandable questions such as, "Is the event date greater than, or less than to 1 January 2003?" and "Is the aircraft registration U.K. or U.S.?" Frequencies for dependent variables were developed through equally simple measures requiring detection of at least one of six possible maintenance error types in the report text and subsequent classification of an accident.

Zikmund (2003) advocated further analysis of measurement criterion validity as the correlation between a proposed measure and a criterion measure. To show concurrent criterion validity, the measurement used in this dissertation was tested against the NASA Aviation Safety Reporting System (ASRS) database and closely approximated the criterion of maintenance error classification in the ASRS. The MEDA tool was used against a sample of 20 ASRS records and the comparison revealed classification agreement between the coders' use of MEDA and NASA classification of maintenance versus nonmaintenance incidents based on a kappa coefficient of .84, described as an "almost perfect" (Semler, 2001, p. 6) agreement.

Operational Definition of Variables

The research database created to investigate Q1 was evaluated to determine the value of the following variables: an independent U.K. human factors regulation variable and a dependent U.K. maintenance-related accident frequency variable. The research database created during the data classification phase of Q2 was evaluated to determine the value of two more variables: an independent U.S. to U.K. human factors regulation variable and a dependent U.S. to U.K. maintenance-related accident frequency variable. Although the titles of the additional Q2 variables are similar to the corresponding variables in Q1, the variables differ in operationalization as described below.

U.K. human factors regulation. This independent variable operationalized the construct of a human factors regulation as the presence or absence of a human factors regulation (as defined by JAR 145) during a specific period. The human factors regulation variable was measured on a nominal scale of two categories: human factors regulations are either present or absent in the U.K. during a particular period. Of the two periods (1995 to 2000 and 2003 to 2008), human factors regulations were in force during the 2003 to 2008 period. Human factors regulations were not in force for aircraft during the 1995 to 2000 period.

U.K. maintenance-related accident frequency. To address Q1, this dependent variable was operationalized as the observed frequency of maintenance-related accidents in the samples. This dependent variable was measured on a ratio scale for U.K.-registered aircraft before and after the 2003 final implementation of human factors regulations in the U.K. The two measurements were used to detect significant changes in the accident frequency during the statistical analysis phase described above. Significant changes in accident frequency detected during chi-square analysis would be used (if warranted) to support rejection of the null hypothesis of no significant difference in accident frequencies before and after implementation of the U.K. regulation.

U.S.-U.K. human factors regulation. This independent variable was used to operationalize the construct of a human factors regulation as the presence or absence of a human factors regulation (as defined by JAR 145) for a specific aircraft registry during a specific period. Human factors regulation was measured on a nominal scale of two categories: human factors regulations are either present or absent based on the particular aircraft registration. For two distinct U.S. and U.K. aircraft registries, human factors regulations were only in force (present) for U.K.-registered aircraft during the 2003 to 2008 period. Human factors regulations were not in force (absent) for U.S.-registered aircraft during the same period.

U.S.-U.K. maintenance-related accident frequency. This additional dependent variable was operationalized as the frequency of maintenance-related accidents occurring among U.S.-registered aircraft during the 2003 to 2008 period in the research database. The variable was measured on a ratio scale for comparison between U.S. and U.K. registered aircraft. Significant differences, determined by evaluation of a chi-square test statistic against a single degree of freedom distribution, between this variable and the U.K. Maintenance-related accident frequency wold (if warranted) result in rejection of the null hypothesis of no significant difference between U.S. and U.K. accident frequencies ($H2_0$).

Data Collection, Processing, and Analysis

The research plan proceeded in sequence, addressing Q1 first. Once data collection, processing, and analysis were completed for Q1, the researcher addressed similar elements for Q2.

Research question Q1. Publically available accident records in the AAIB databases were accessed and transferred to a spreadsheet application and used to create two manageable research databases:

- U.K. records 1995 to 2000
- U.K. records 2003 to 2008

Processing. To produce the U.K. 1995-2000 sample (Appendix B), the AAIB database was filtered for fixed wing (airplane), public transport (commercial) records. This filter yielded 644 records for transfer to the research database on 5 January 2011. Once in the research database, a further 187 non-U.K. registered aircraft records were discarded. A 138-record random sample was extracted from the remaining 457 records for classification through the MEDA-analysis. During the initial MEDA-analysis, a further 12 records were discarded as mismarked helicopter records, corrections and addenda unrelated to the remaining sample, and records (hyperlinks) unable to be executed. These discarded records were replaced through random sampling from remaining records in the research database. A similar procedure started on 8 January 2011 when 440 2003-2008, fixed-wing, public transport records were transferred to a second research database (U.K. 2003-2008); 161 non-U.K. registered aircraft records were discarded before extracting the 138-record random sample (Appendix C). Like the previous sample, a further 13 records were discarded for similar reasons and replaced through further random sampling.

While classification by period is relatively straightforward (AAIB records are already categorized by date of incident), classifying reports by type of accident requires a more detailed analysis. Consequently, each record underwent quantitative content analysis as described by Duriau et al. (2007) using the MEDA as predetermined criteria to assess the type of accident. The MEDA is an error taxonomy system defining six types of maintenance errors; detection of one or more of the following MEDA errors in an accident report classified the report as maintenance related (Rankin et al., 2000):

1. Installation error (part not installed or installed improperly)
2. Servicing error (system not serviced or under- or over-serviced)
3. Repair error (repair not accomplished, repair incomplete)
4. Inspection error (detectable error not detected, inspection not performed)
5. Foreign object error (debris, material, or tools left in the aircraft)
6. Equipment error (defective tools or improper use of tools and equipment).

This use of the MEDA as predetermined criteria to distinguish maintenance-related accidents from other non-maintenance-related accidents established maintenance-related accident frequencies for the periods under review. Failure to classify at least one error in a suspected maintenance-related accident report into at least one of the above error categories resulted in classification as a nonmaintenance-related accident. Although the MEDA analysis includes a seventh category for personal injury error, this category was not included in the research. In the event a mechanic's personal injury results in some form of maintenance error in an aircraft system, (e.g., the mechanic falls from a maintenance stand, strikes and damages flight control, damage goes unnoticed and is reported in subsequent aircraft accident investigation), the error was reported as equipment error (improper use of tools or equipment) and included suitable explanatory annotation.

Analysis. Norusis (2006) and Lenell and Boissoneau (1996) recommended cross tabulation and chi-square analysis to detect differences between samples in terms of frequencies rather than comparison of arithmetic means (averages of accidents). The results of the accident record analysis were collected as the frequency of accident classifications and cross tabulated in a 2X2 matrix (maintenance-related and non-maintenance-related accidents versus periods 1995-2000 and 2003-2008).

Table 1

Cross tabulation of UK Time Periods versus Accident Classification (Y)

			Accident Classification		
Nation	Time Period	Frequency	Maintenance	Non-maintenance	Totals
UK	1995-2000	Observed	Y_{1obs}	Y_{2obs}	$Y_{1obs}+Y_{2obs}$
		Expected	Y_{1ex}	Y_{2ex}	
		Residual	Y_{1res}	Y_{2res}	
UK	2003-2008	Observed	Y_{3obs}	Y_{4obs}	$Y_{3obs}+Y_{4obs}$
		Expected	Y_{3ex}	Y_{4ex}	
		Residual	Y_{3res}	Y_{4res}	
Total			$Y_{1obs}+Y_{3obs}$	$Y_{2obs}+Y_{4obs}$	$Y_{1obs}+Y_{3obs}+Y_{2obs}+Y_{4obs}$

The cross tabulation provided a method for comparing expected to actual accident frequencies by calculating a residual difference between actual and expected frequencies, where:

Y_{1obs} = observed (actual) maintenance related frequency 1995 to 2000

$$Y_{1ex}\text{ (expected frequency)} = \frac{(Y_{1obs}+Y_{2obs})(Y_{1obs}+Y_{3obs})}{(Y_{1obs}+Y_{2obs}+Y_{3obs}+Y_{4obs})}$$

Y_{1res} (residual difference) = $Y_{1obs} - Y_{1ex}$

Similar calculations were used for Y_2, Y_3, and Y_4.

The matrix was evaluated to determine the existence of significant residuals through chi-square analysis of the following test statistic:

$$\chi^2 = \sum_{m=1}^{4} \frac{(Y_{mres})^2}{Y_{mex}}$$

For this test statistic, χ^2 was calculated as the summation of the ratio of the squares of the residual to expected frequencies using a spreadsheet chi-square calculator. The test statistic was evaluated against a critical value of 2.706 established by a significance level (alpha) of .10 and the cross tabulation's 1 degree-of-freedom (a constraint of the 2 X 2 matrix) to determine the significance of the residuals within the matrix. If the chi-square test statistic falls beyond the critical value, the null hypothesis would be rejected; the rejection would support an alternate hypothesis of significant change in the U.K. rate (between the periods before and after the human factors regulation was implemented). The results of this analysis are presented in Chapter 4 (the spreadsheet output of the chi-square calculator is presented in Appendix F). A similar procedure was used to evaluate the null hypothesis derived from Q2 (a comparison of U.S. and U.K. rates).

Research question Q2. To triangulate the results of Q1, a similar procedure was used to address Q2 using U.S. accident records. Investigation of Q2 began by accessing publically available accident records in the NTSB database. Commercial aircraft accident records (2003-2008) were transferred to a spreadsheet application to create a third research database similar to those created in Q1.

Processing. NTSB accident records were processed using the procedure described for Q1 to ensure U.S. accident classification frequencies are suitable for comparison with existing U.K. frequencies from Q1. Since the NTSB system filters were set for the following parameters:

Date Range: 1 January 2003 to 31 December 2008

Operation: FAR Part 121 and 135

Category: airplane

Registration: U.S.

Status: probable cause

These filter setting yielded 646 records on 10 January 2011; a 138-record random sample was extracted for MEDA-analysis (Appendix D). Unlike the U.K. samples above, there were no mismarked records or non-accident reports; instead, five records were discarded for inability to execute the hyperlink to the report; suitable annotations were added to the research database. These discarded records were replaced through random sampling of the remaining records in the research database.

Analysis. In the evaluation of Q1 accident frequencies, national registry (U.K.) was held constant and the independent variable (human factors regulation) was based on the period (before or after regulation). In the evaluation of Q2 accident frequencies, the period (2003-2008) was held constant and the independent variable (human factors regulation) was based on national registry of the aircraft (U.K. or U.S.). The results of the accident record analysis were collected as the frequency of maintenance-related accidents and cross tabulated in a 2 X 2 matrix (U.S. and U.K. versus maintenance- and non-maintenance-related accidents).

Table 2

Cross tabulation of Nation versus Accident Classification (Z)

Nation	Time Period	Frequency	Accident Classification Maintenance	 Non-maintenance	Totals
UK	2003-2008	Observed	Z_{1obs}	Z_{2obs}	$Z_{1obs}+Z_{2obs}$
		Expected	Z_{1ex}	Z_{2ex}	
		Residual	Z_{1res}	Z_{2res}	
US	2003-2008	Observed	Z_{3obs}	Z_{4obs}	$Z_{3obs}+Z_{4obs}$
		Expected	Z_{3ex}	Z_{4ex}	
		Residual	Z_{3res}	Z_{4res}	
Total			$Z_{1obs}+Z_{3obs}$	$Z_{2obs}+Z_{4obs}$	$Z_{1obs}+Z_{3obs}+Z_{2obs}+Z_{4obs}$

The use of cross tabulation provided a method for comparing expected to actual accident frequency by calculating a residual difference between actual and expected frequency, where:

Z_{1obs} = observed (actual) maintenance related frequency in sample 1 (U.K. 2003-2008)

Z_{1ex} (expected frequency) = $\dfrac{(Z_{1obs}+Z_{2obs})(Z_{1obs}+Z_{3obs})}{(Z_{1obs}+Z_{2obs}+Z_{3obs}+Z_{4obs})}$

Z_{1res} (residual difference) = $Z_{1obs}-Z_{1ex}$

Similar calculations were used for Z_2, Z_3, and Z_4.

The matrix was evaluated initially to determine the existence of significant residuals through analysis of the following chi-square test statistic:

$$\chi^2 = \sum_{m=1}^{4} \frac{(Z_{mres})^2}{Z_{mex}}$$

χ^2 was calculated as the summation of the ratio of the squares of the residual to expected frequencies using the same spreadsheet calculator used in Q1. To determine the significance of the residuals within the matrix, the test statistic was evaluated using the same criteria found in Q1: critical value (2.706), alpha (.10), and 1 degree-of-freedom (a constraint of the 2 X 2 matrix). χ^2 values exceeding the critical value would support rejection of the Q2 null hypothesis ($H2_0$) of no significant difference between U.S. and U.K. frequencies. The results of this analysis are presented in Chapter 4 (the spreadsheet output of the chi-square calculator is presented in Appendix F).

Methodological Assumptions, Limitations, and Delimitations

Assumptions. The central assumption of the dissertation research is that intervention to provide human factors regulation for aircraft maintenance personnel will have a detectable effect on a nation's maintenance-related accident rate. The quality of this research is based on assumptions about the accuracy of two critical components: accident reports as data, and the MEDA as the measurement instrument. Wells and Rodrigues (2003) described the AAIB and NTSB accident investigating systems as the international standard in the accident investigation field. Thus, the reports and conclusions of the investigations were considered accurate. The MEDA is assumed to be an accurate tool for detecting maintenance error based on its prior successful use in research (Rankin et al., 2000) and reliability testing conducted by Hobbs and Williamson (2003).

The salient difference between Q1 and Q2 is the data triangulation using a third research database taken from NTSB records in the U.S. In addition to assumptions concerning databases and instruments in Q1, research into Q2 thus has an additional assumption of the comparability of the U.S. and U.K. aviation systems, which was considered among the following limitations of the study.

Limitations. Limitations in the research were in the form of internal and external threats common to ex post facto designs (Cohen, Manion, & Morrison, 2000). Internal threats include the lack of treatment and control groups as well as the inability to establish identical groups for comparison; these threats are used to form the basis of common, confounding variables in ex post facto research (Lord, 1973). Delimitation of the study to a single nation for the evaluation of Q1 hypotheses, in an attempt to reduce the effect of cultural differences, also presented a further limitation in the form of the external threat to generalizability of the results of the study to mechanics in other nations. When compared to Q1, research of Q2 was exposed to slightly different limitations to those encountered in Q1. These additional limitations are discussed in each subsection below.

Lack of treatment and control groups. As an investigation of historical events, an ex post facto analysis does not involve distinct, randomly selected treatment and control groups, nor does it involve random assignment of cases to groups. Knowledge of effective human factors practices may have arisen spontaneously among mechanics and maintenance organizations prior to implementation of the regulation. In theory, this prior knowledge during the 1995 to 2000 period could have reduced the magnitude of the effect of the 2003 final implementation of JAR 145. This limitation is encountered and accepted in historical ex post facto research because it is near impossible to demonstrate the historical absence of a particular knowledge in a particular group (Ary, Jacobs, Razavieh, & Sorensen, 2009; Lord, 1973).

A similar problem exists for the investigation of Q2. Since nothing prevents information from passing between nations, or simultaneous, spontaneous awareness in both nations, control of human factors awareness could not be experimentally limited to a treatment group. Thus, the group without human factors regulations in place might have voluntarily adopt practices seen as good ideas while observing the other group. This is indeed the case when the U.S. officials take note of the human factors efforts of foreign aviation organizations, publish recommendations, and promote voluntary programs based on these observations (Hackworth et al., 2007). In spite of this contamination between groups, in the study of maintenance organizations Hackworth et al. concluded that organizations in countries with regulations have more robust human factors programs than those that do not. In the opinion survey, it was concluded that organizations in which leaders are operating under regulations mandating human factors programs were more effective in preventing accidents. While knowledge of human factors may have existed among U.S. organizations and lessened the relative effect of a regulation, the presence of regulation among U.K. organizations should have the observable, beneficial effect posited by Baron (2009), Hackworth et al. (2007), and Hobbs and Williamson (2003).

Lack of comparable populations. Peters (2005) investigated how changes in government institutions affect organizations and noted several confounding variables interfered with accurate prediction of effect. Peters perceived that the lack of real support for new regulations, cultural differences entrenched within and without the organization, and economic circumstance may all conspire to inhibit an organization's investment to achieve compliance, and ultimately, the goals of the new regulation.

Ex post facto research is fraught with inherent problems of establishing causality due to the inability to control confounding variables. A cultural change in the attitude of U.K. mechanics coinciding with the implementation of new regulation may have resulted in greater diligence among mechanics unrelated to the implementation of the regulation. An unrelated coincident technology or procedural improvement may have facilitated the quality of the mechanics' work, thus reducing the incidence of maintenance error from one period to the next. Alternatively, the human factors regulation may be driving the technology or procedural change as an intervening variable and thus causing the changes in the dependent variable. Although cultural examples may be used to illustrate the difficulty of establishing causality without the controls of the experimental method, Oliver (1991) noted that cultural changes occur over generations, not years, and posited that regulations had a more immediate effect than cultural adaptation. Conclusions of the dissertation research relied on this concept of immediate effect within the U.K. mechanic population.

Q2 was used to expand the question beyond the bounds of the U.K. culture and includes the U.S. culture in the problem of comparability between groups. In discussing the comparison of two countries, Peters (2005) noted culture to be a confounding variable; members of different cultures will have different approaches to enforcement and compliance with regulations. Since no universal ethical code exists to govern behavior (Gauthier, Pettifor, & Ferrero, 2010), it is difficult to guarantee that members of two cultures will respond in the same way to a new regulation. For example, bribery is frowned upon and legislated against in the U.S. as unethical, yet it is the customary method for getting things done more efficiently in many cultures (Verschoor, 2007). Although excoriated in one country, bribery may be celebrated in another country and embedded in the ethics of that society. Stuart (2005) countered this limitation and described the U.S. and U.K. as having a common culture composed of closely related legal, economic, and regulatory models. The confounding effect of culture is partially mitigated by comparing what Stuart described as the two most closely related populations, the U.S. and U.K.

Setting aside Stuart's (2005) assurances of similarities between the U.S. and U.K., cultural differences between the two nations with regard to each group's predilection for following regulations impacts the ability of the method to detect changes related solely to implementation of a new regulation. Although Stuart found the U.S. and U.K. to have a common culture, these naturally occurring groups of mechanics cannot be compared demographically. While U.S. and U.K. mechanics may be the closest cultural groups available for study, the two are still distinct components in a single Anglo-Saxon culture (Haglund, 2005) and can never be culturally or demographically identical.

External threat to generalizability. Although the dissertation study was delimited to specific nations in specific periods immediately before and after an event to facilitate the most accurate ex post facto comparison possible, it represents an external threat to validity in the form of generalizability of results. In experimental research, generalizability is established with a random sampling technique to ensure the sample is demographically representative of the population. Since commonly accepted sampling techniques were used in the study, validity of generalization of the results from sample statistic to estimates of a U.K. or U.S. population parameter is enhanced (Norusis, 2006; Trochim & Donnelly, 2008). However, the enhancement cannot be used to imply that results of this study are suitable for generalization across the entire international air transportation system. Consequently, generalization of results to other countries in other periods remains at the discretion of future researchers.

Delimitations. The study was delimited to U.K. and U.S. regulations and performance. In its data collection, the investigation was delimited to accident reports involving aircraft engaged in FAR Part 121 and 135 operations and the similar U.K. Public Transport aircraft classification. The study was also delimited to accident reports of events occurring between 1995 and 2008 to maintain the database at a manageable size, ensure time constraints of the dissertation program were met, and simultaneously achieve the larger sample size necessary to counter the anticipated effect size.

Ethical Assurances

Lacking human participants, no ethical difficulties were encountered in the dissertation study. Institutional Review Board approval was obtained before data collection began.

Summary

The research problem and purpose were addressed through a quantitative ex post facto analysis of aircraft accident reports. A quantitative method was selected based on the stated research purpose to quantify and compare the accident rate performance of two nations, the U.S. and U.K. The historical aspect of the events defining the problem and the consequent inability to manipulate variables or randomly assign cases to control or experimental groups influenced the selection of a quantitative ex post facto design (Lord, 1973). The same factors influencing the selection of the ex post facto design were used to highlight the weaknesses of the dissertation study, yet within the stated limitations, the research may make “extremely valuable contributions to our knowledge that otherwise might not be obtained” (Wogalter, DeJoy & Laughery, 1999, p. 61). Cohen et al. (2000) echoed this conclusion as they described ex post facto research as “a valuable exploratory tool” and its ability to meet “an important need of the researcher where the more rigorous experimental approach is not possible” (p. 208). Although this inability to control variables and groups limits the design’s capacity to establish a definitive cause-and-effect between the variables, the design was able to address the research purpose of exploring the effect of regulations by detecting and analyzing the significance of changes in U.S. and U.K. maintenance related accident rates (Ary et al., 2009).

Chapter 4: Findings

The purpose of this quantitative study was to explore the postulate (Baron, 2009; Hackworth et al., 2007; Hobbs & Williamson, 2003) that human factors regulation would reduce maintenance related accidents by analyzing and comparing changes in U.S. and U.K. accident rates to detect and evaluate the effect of regulations. To achieve this purpose, two research questions evolved:

Q1. To what extent does a statistically significant difference exist between the U.K. maintenance accident rate before (1995-2000) and after (2003-2008) the implementation of human factors regulations?

Q2. To what extent does a statistically significant difference exist between U.S. and U.K. maintenance related accident rates during the period (2003-2008) that U.K. regulations were in force?

Responses to the research questions were arrived at in accordance with the research design detailed in Chapter 3. A series of hypotheses were developed to support significance-testing necessary to answer the above questions:

$H1_0$. No statistically significant difference exists between the U.K. maintenance related accident rates in the specified periods.

$H1_a$. A statistically significant difference exists between the U.K. maintenance related accident rates in the specified periods.

$H2_0$. No statistically significant difference exists between U.K. and U.S. maintenance related accident rates in the specified period.

$H2_a$. A statistically significant difference exists between U.K. and U.S. maintenance related accident rates in the specified period.

The remainder of this chapter is organized around the above research questions and attendant null hypotheses. This chapter provides a description of the samples and the results of the raw numerical comparison of the samples as well as the significance testing by chi-square analysis. This chapter also includes an evaluation and summary of the findings presented.

Results

Exploring changes in the U.K. accident rate. To answer Research Question 1, all AAIB accident records from two periods were transferred to a research database: one from a period before U.K. regulations were implemented and one from a period after regulations were implemented.

Description of samples. The final U.K. 1995-2000 sample (Appendix B) consisted of 138 fixed wing, public transport category aircraft accidents. The MEDA analysis classified 37 reports (27%) as maintenance related accidents and the remaining 101 as nonmaintenance related accidents. Within these 37 accidents, Table 3 shows how the 49 maintenance errors were classified (some maintenance related accident reports find more than one error maintenance error during the investigation):

Table 3

U.K. 1995-2000 Accidents by Error Category

Error	Frequency
Installation	10
Servicing	0
Repair	6
Inspection	10

Foreign object	3
Equipment	20

During MEDA analysis of the U.K. 2003-2008 sample (Appendix C), 29 reports (21%) were classified as maintenance related accidents. As shown in Table 4, these 29 reports contained 39 maintenance errors in the following MEDA error categories:

Table 4

U.K. 2003-2008 Accidents by Error Category

Error	Frequency
Installation	7
Servicing	4
Repair	4
Inspection	7
Foreign object	1
Equipment	16

Comparison of U.K. 1995-2000 to U.K. 2003-2008. The U.K. 1995-2000 maintenance related accident count of 37 (27%) was compared to the U.K. 2003-2008 maintenance related accident count of 29 (21%). The presence of the regulation did not significantly affect the U.K. 2003-2008 accident rate, $\chi^2(1, N = 276) = 1.27, p = .26$. This score did not meet the established critical value for significance of 2.71 ($p \leq .10$). The null hypothesis $H1_0$ of no significant difference between U.K. maintenance related accident rates before and after regulation were implemented, was not rejected.

Exploring the differences between U.S. and U.K. accident rates. To address the second research question of significant differences between U.S. and U.K. accident rates, the post-regulation time periods were examined in each nation. A chi-square analysis was performed using the frequencies from the U.S. sample below and the U.K. 2003-2008 sample drawn in the investigation of the first research question.

Description of sample. Within the U.S. 2003-2008 sample (Appendix E), the MEDA analysis classified 23 reports (17%) as maintenance related accidents. In Table 5, these 23 reports contained 27 maintenance errors in the following MEDA categories:

Table 5

U.S. 2003-2008 Accidents by Error Category

Error	Frequency
Installation	4
Servicing	2
Repair	5
Inspection	7
Foreign object	0
Equipment	9

Comparison of U.K. 2003-2008 to U.S. 2003-2008. The U.K. maintenance related accident count observed in the 2003-2008 sample was 29 (21%) and the U.S. count in the same period was 23 (17%). The presence of the regulation did not significantly affect the U.K. accident rate when compared to the U.S. rate, $\chi^2(1, N = 276) = .85, p = .36$. This score was not significant when compared to the critical value of 2.71

($p \leq .10$). Null hypothesis $H2_0$ of no significant difference between U.K. (with regulation) and U.S. (without regulation) maintenance related accident rates in the 2003-2008 time period, was not rejected.

Additional findings. Although formal research questions and hypotheses to investigate changes in the U.S. accident rate or compare U.S. and U.K. performance in the pre-regulation period were not developed, the rejection of alternate hypotheses of significant changes in U.K. rates and significant differences in U.S. and U.K. rates drove the exploration into these areas. A sample of commercial accident records was taken from the NTSB database for the 1995-2000 period (Appendix D).

Description of Sample. On 11 January 2011, all U.S. accident reports were extracted from the NTSB database for the period 1 January 1995 to 31 December 2000 to provide a baseline for U.S. accident rate performance. The NTSB database was filtered for the following five parameters:

Date: 1 January 1995- 31 December 2000
Category: Airplane
Registration: N
Operation: Part 121 and Part 135
Report Status: Probable cause

After filtering, 963 NTSB records were transferred to the U.S. 1995-2000 research database and a 138-record sample was taken. Like the U.S. 2003-2008 sample, the transfer contained no foreign registered aircraft. Of the 138 records in the sample, 13 reports were discarded and replaced due to invalid addresses (hyperlinks) that could not be executed.

Within the sample, the MEDA analysis classified 31 reports (22%) as maintenance related accidents. These 31 reports contained 35 maintenance errors in the following MEDA categories shown in Table 6:

Table 6

U.S. 1995-2000 Accidents by Error Category

Error	Frequency
Installation	7
Servicing	2
Repair	9
Inspection	6
Foreign object	1
Equipment	10

Additional analysis of U.S. accident rates. Chi-square comparisons between U.S. accident rates in periods 1995-2000 and 2003-2008 (a before and after comparison in a nation where no regulation was implemented) were conducted. While no formal hypothesis testing of this data was required by the research plan, the 1995-2000 count of 31 (22%) and the 2003-2008 count of 27 (17%) did not represent a significant change in the U.S. maintenance related accident rate in the specified time periods $\chi^2(1, N = 276) = 1.47, p = .23$. This chi-square test statistic did not meet the critical level of 2.71 ($p \leq .10$).

A final test was conducted to establish the relationship between U.S. and U.K. aircraft maintenance performance in terms of maintenance related accident rates prior to the implementation of regulations in the U.K. U.K. 1995-2000 and U.S. 1995-2000 maintenance related accident counts of 37 (27%) and 31 (22%) respectively. There was no significant difference between U.S. and U.K. rates in the 1995-2000 time period, $\chi 2(1, N = 276) = .70, p = .40$. This score was below the critical value of 2.71 ($p \leq .10$) and indicated no significant difference in the maintenance performance between the two nations in the period before U.K. regulations were implemented.

In order for the above chi-square analyses to test the significance of any changes in the frequency of accidents two assumptions must be met. First, each record contributes to the frequency of only one cell in the crosstabulation. Second, an adequate approximation of the chi-square statistic requires at least 20 records. In the case of this dissertation research, neither of these assumptions was violated. In the specific language-format of the chi-square analysis, the variables (regulation and maintenance accident frequency) were found to be independent in both research questions as well as the additional findings; that is, changes in the dependent variable were independent of changes in the independent variable. Consequently, it is unlikely a relationship exists between the variables in this analysis.

Equipment error findings. The equipment error category listed in the results above was defined and initially intended to capture instances of inappropriate use of equipment, but rapidly filled with instances of tow vehicles, baggage loaders, and stair trucks impacting and damaging aircraft. While these errors undeniably meet the criteria of inappropriate use of equipment, they were also the most prevalent errors in the samples. Looking at the entire dataset of all four samples, the equipment error category accounted for 36% of all errors and was the leading error category in each sample. As an example, Table 7 shows the U.K. 2003-2008 sample (where the literature predicted reduced accident rates as a result of human factors regulations), percentage of total errors in each error category were as follows:

Table 7

U.K. 2003-2008 Error Rate by Error Category

Error Category	Error Rate (%)
Installation	18
Servicing	10
Repair	10
Inspection	18
Foreign object	2.5
Equipment	41

Table 8 shows this equipment error mode was found in each sample, regardless of location or time period. Although the U.S. equipment error rates were less than those found in the U.K. samples, the U.S. rates experienced a slight increase over the period of the study.

Table 8

Equipment Error Rate in U.S. and U.K. Samples

Sample	Equipment Error Rate (%)
U.K. 1995-2000	40
U.K. 2003-2008	41
U.S. 1995-2000	28

U.S. 2003-2008	33

It is important to note that JAR-145 human factors training applies to these ground handling crews as well as the aircraft mechanic (who is often the focus of maintenance human factors discussion) (CAA, 2004). In spite of their inclusion under JAR 145 human factors requirements, ground-handling personnel have no technical training standard for identifying aircraft structural damage (CAA, 2006).

Evaluation of Findings

It is also important to note that this research centered on the implementation and enforcement of a human factors regulation for maintenance organizations. These aviation organizations coexist within an institutional ecology alongside their regulators and peer organizations. In this study, the knowledge of human factors hazards, passed informally among mechanics and organizations, was sufficient to decrease accident rates in the U.S., and the contribution of subsequent regulation produced only an additional 1% decrease (the U.S. and U.K. rates declined by 5% and 6%, respectively) in the U.K. In this light, the effect of the regulation on the institutional ecology of aviation maintenance is even less significant.

Institutional and organizational behavior. The theoretical framework for this research relied on a synthesis of institutionalism, organizational evolution, and rational action theories. These theories present the concept of an institutional ecology in which survival and legitimacy are primary goals of the organization. As regulators impose new regulations to achieve the aims altering the ecology, organizations adapt themselves, to a greater or lesser extent, to the new ecology and thus the aims of the regulator (Argote &

Greve, 2007). The motivator for this behavior is the regulators power to affect the organizational revenue-source by revoking licenses or certificates (deJonge, 2005). Faced with a form of extinction, organizational leaders behave rationally and conform to regulations and evolve into organizations with characteristics desired by the regulator (Poirot, 2008); alternatively, there may be unintended consequences as organizations attempt to evade the requirements imposed upon them (Ockree & Martin, 2009). The new ecology in aviation is safer air transportation with consequently fewer accidents (Hackworth et al, 2007). Thus measuring accident rates before and after regulation should reveal an impact on the institutional behavior (Dobrev, Kim, & Carroll, 2003). Conversely, measuring these same rates in organizations where regulation was not implemented should demonstrate no significant decrease and consequently higher accident rates when compared to the regulated organization. This new ecology was not detected in the samples of this study.

Unlike Ockree and Martin's 2009 analysis of the effects of the Sarbanes-Oxley Act on SEC-listed companies, aviation organizations cannot delist themselves from the FAA; it is not a voluntary association. The aviation organization in the U.S. or U.K. must apply to the regulator and meet certain requirements in order to receive, and keep, an operating certificate. Since JAR-145 certification of a maintenance organization requires an acceptable human factors program, the U.K. organization must produce such a program to avoid suspension or revocation of the operating certificate. Thus while SEC-listed companies could disassociate themselves from the SEC and regulation and thereby avoid the burdens of ethics regulation by going private (but continuing to operate) (Ockree & Martin, 2009), aviation U.K. aviation organizations should have adopted human factors requirements or abandoned the institution by going out of business.

Hackworth et al's. (2007) international survey confirmed that U.K. organizations subject to JAR-145 had indeed implemented the requirements of the regulation. This dissertation research failed however, to confirm that the regulation (according to institutional theory) had a significant affect on the institutional ecology: a significantly safer institutional ecology (in terms of fewer aviation accidents) was not achieved in the U.K. Although a portion of institutional literature pressed the predictive power of institutional research (Oliver, 1991; King et al, 2009), this result seems to support the opposing view that the myriad individual behaviors making up an organization make prediction of the new ecology impossible (FAA, 2007; Frahm, 2007; Poirot, 2008).

Turning to the more focused theories of aviation organizations, the findings in this research seem to contradict the prevalent theory (held by the CAA) that human regulation will affect the maintenance error rate, reduce maintenance related accidents, and ultimately result in a safer air transportation system (CAA, 2009). Instead, the findings support the dissenting theory (adopted by the FAA) that human factors are a predominately affected by individual behavior and too complex to be controlled by regulation (FAA, 2007).

In reference to accident rates (a common element of studies found in the literature), the findings of this study also highlight agreements and disagreements with previous research. Differences observed between the accident rates in this study and in the literature were expected; the literature review revealed no universal standard for classifying accidents as maintenance related. The dissertation researcher did expect to find a much lower rate given the strict classification protocol outlined in Chapter 3. The much higher rates revealed in this study were commensurate to those found in studies reviewed by Dhillon and Liu (2006) and Hackworth et al. (2007). While the estimates of maintenance related accident rates from this research fell within the range of estimates in the literature, substantial disagreement arose between the estimates in this research and the CAA's maintenance error estimate of 6%. While the CAA touts the decline in the MORS maintenance error rate as evidence of the effectiveness of the JAR 145 human factors program (CAA, 2007), the expected, significant decrease in the U.K. accident rate predicted by the MORS error rate was not evident in the results of this research. Unlike the disparity between U.K. rates and the results of this research, the U.S. 2003-2008 sample's accident rate 17% approximated the FAA-estimated 15% maintenance related accident rate.

The FAA did not implement regulations but instead embarked on an awareness campaign to inspire voluntary compliance and the adoption of some form of human factors program among maintenance organizations. While this research was not intended to explore the effects of the FAA's awareness campaign, the U.S. 1995-2000 sample had a maintenance related accident rate of 23% and this rate fell to 17% in the U.S. 2003-2008 period. The assumption of the research was that the U.S. rate would remain relatively stable in the absence of a regulation or trigger a decrease (though not commensurate to the decrease in U.K. rates) as the FAA awareness campaign proceeded. Instead, the downward move in the U.S. accident rate was not significant but was similar to the U.K. rate-decrease; U.S. and U.K. accident rates fell by 5% and 6% respectively. In addition, a comparison of 2003-2008 rates shows the U.S. outperforming U.K.

maintenance with accident rates of 17% and 21% respectively. While not significant difference, it must be noted the U.S. lead comes without the benefit of a human factors regulation.

Focusing on equipment error. Although not addressed as a separate research question, ground handling personnel appear to have something of a real time, pilot-like environment (unlike the more sedate pace of maintenance where care can be taken to rework errors detected in subsequent inspection and ensure work is accomplished properly). While the ground handling environment is certainly less complex than the cockpit environment, they are similar in that both involve vehicle movement and real-time decision-making of the operator (Edkins, 2002). The ramp environment is also subject to the vagaries of weather such as icy surfaces and poor visibility contributing to error rates. At larger, busier airports, the interaction between tow team, aircrew, ramp controllers, air traffic ground controllers, baggage loaders, cargo team, and taxiing aircrews can become quite complex as the entire staff is making last-minute decisions immediately before launch to accommodate last-minute decisions of other staff members (Edkins, 2002). In these samples, most damage to the aircraft occurred as vehicles of all descriptions collided with parked aircraft. In addition, ground crews marshaled (provided hand-signals to guide pilots or tow teams in maneuvering the aircraft on ground) aircraft into collisions with other aircraft, parked equipment, and buildings. Equipment error was the leading category of error in all samples.

Summary

Chi-square comparison of samples was conducted between nations and time periods. There were four comparisons:

1. U.K. 1995-2000 compared to U.K. 2003-2008
2. U.S. 1995-2000 compared to U.S. 2003-2008
3. U.K. 1995-2000 compared to U.S. 1995-2000
4. U.K. 2003-2008 compared to U.S. 2003-2008

No significant differences were detected in the comparisons. Neither $H1_0$ nor $H2_0$ was rejected.

The response to Research Questions 1 is: No, there was no significant difference between U.K. maintenance accident rates before and after human factors regulations were implemented.

The response to Research Question 2 is: No, there was no significant difference between U.S. and U.K. maintenance accident rates after human factors regulations were implemented in the U.K.

Although the statistical analysis of the data failed to confirm the predicted, significant change in accident rates, the analysis revealed a statistical similarity between U.S. and U.K. performance improvement (chi-square of 1.47 and 1.27 respectively). In a static comparison of U.S. and U.K. data, the two aviation systems were also remarkably similar (chi-square of .7 before and .85 after the U.K. regulation). Table 9 presents phi coefficients for each crosstabulation to facilitate comparison between the above chi-square scores. Comparison of phi-coefficients confirmed the similarities in both static and dynamic performance between the U.S. and U.K. data:

Table 9

Phi Coefficients of 1995-2000 to 2003-2008 and U.S. to U.K. Comparisons

Comparison	Phi Coefficient

U.K. 1995-2000 compared to U.K. 2003-2008	.096
U.S. 1995-2000 compared to U.S. 2003-2008	.103
U.K. 1995-2000 compared to U.S. 1995-2000	.071
U.K. 2003-2008 compared to U.S. 2003-2008	.079

Overall, this result fails to support the common view of both institutional and aviation theory concerning the effectiveness of regulation in controlling the institutional ecology and human factors in maintenance. The results instead indicate that the implementation of U.K. human factors regulation had no significant effect on the U.K. accident rate, nor was the U.K. post-regulation accident rate significantly lower than the U.S. accident rate. Based on the above results, this research has shed new light on the fields of institutionalism and aviation maintenance. In the case of the U.S. and U.K., the two national aviation institutions did not react or compare as theory in either field predicted.

Chapter 5: Implications, Recommendations, and Conclusions

The problem addressed in this research was that the U.S. maintenance related accident rate was higher than the U.K. maintenance related accident rate (Aslanides et al., 2007; Hackworth et al., 2007; Majumdar et al., 2009). Hackworth et al. (2007) noted the problem of the higher U.S. accident rate in their study of international maintenance human factors programs. Aslanides et al. (2007) and Majumdar et al. (2009) also noted that human factors related accidents represented a threat to aviation safety. Fogarty (2004) echoed these concerns and described human factors training as a key component of improved safety performance. In light of the above problem, a quantitative ex post facto content analysis of accident records was used to explore the postulate (Baron, 2009; Hackworth et al., 2007; Hobbs & Williamson, 2003) that human factors regulation would reduce related accidents. This exploration was achieved by analyzing and comparing changes in U.S. and U.K. accident rates to detect and evaluate the effect of human factors regulations for aviation maintenance organizations.

Limitations in the research were in the form of internal and external threats common to ex post facto designs (Cohen, Manion, & Morrison, 2000). Internal threats include the lack of treatment and control groups as well as the inability to establish identical groups for comparison; these threats form the basis of common, confounding variables arising from the comparability of groups as well as the lack of strict isolation between groups (Lord, 1973). Delimitation of the proposed study to two nations, in an attempt to reduce the effect of cultural differences, presented a further limitation in the form of the external threat to generalizability of the results of the proposed study to organizations in other nations.

As described above, the focus of the research was on content analysis and classification of accident records to develop accident rates for comparison between samples. With no human participants, the study encountered no ethical difficulties during the process of the research. The remainder of this chapter presents implications and recommendations of the results of the research in addressing each research question as well as a summary of its contents.

Implications

The significance of the research reported in Chapter 1 focused on the cost to aviation operations in terms of damaged and lost aircraft as well as lost custom from passengers concerned about airline safety (Squalli & Saad, 2006). The unexpected results of this research have turned this concept of significance around to question the return-on-investment of human factors programs for maintenance. The dissertation researcher expected that U.K. data would reveal a significant decline in maintenance related accidents and that a comparison between the U.S. and U.K. would serve only to further confirm this. This led the researcher to believe that the dissertation would satisfy Franco's (2008) call for evidence to support the implementation of a new regulation in the face of scarce financial resources available to aviation organizations. The results do provide Franco's required evidence, but perhaps not the expected evidence.

Arguably, the lack of control inherent in the ex post facto structure of this analysis makes a definitive causal conclusion based on these findings inappropriate. In these samples, no relationship was detected and thus no causal relationship exists between the human factors regulation and the maintenance related accident rate. In discussing the hazards of deducing cause and effect based on the results of an ex post facto analysis, Lord (1973), Chandra and Sharma (2004), and Singh (2008) all echoed Tuckman's (1972) original caveat of ex post facto research:

> It is not always possible to assume a simple causative relation between independent and dependent variables. If the relationship fails to be obtained, then it is likely that no causative relationship holds. But if the predicted relationship is obtained this does not necessarily mean that variables studied are causally related (p. 123).

Consequently, the lack of a relationship between the samples in this study makes it likely that no causal relationship exists in the broader population of U.S. and U.K. aircraft accidents.

Interpretation of the results of this research is affected by the above inherent limitations of the ex post facto method. These limitations give rise to two distinct problems of generalization: First, the generalization of sample estimations to the population parameters of U.S. and U.K. accidents and second, generalization of results to the greater population of aircraft accidents of all nations. In the first case, random sampling procedures used provide adequate statistical basis for accepting the sample estimate as a sound approximation of the population parameter and the subsequent comparisons between samples as a proxy for comparisons between time periods and the specific nations investigated in the study. In the second case however, the strict limitation of the research to the two most comparable maintenance populations precluded any statistical basis for generalizing the results to mechanics and regulatory agencies of nations outside the study. Similar restrictions to specific time periods likewise render the results inapplicable to other periods.

In addition to the lack of significant effect on maintenance related accident rates, a second implication arises from the results of this study: the CAA reliance on the MORS error rate may not be an appropriate measure of the effect of human factors regulation. Theoretically, the low U.K. maintenance error rate should have resulted in an even lower maintenance related accident rate based on Reason's (2004) model of error and accident commonly known as the Swiss Cheese model. Reason hypothesized that most accidents were a result of organizational influences, unsafe supervision, preconditions for unsafe acts, and the unsafe acts themselves. An aviation organization built layered defenses against error and each of these layers was characterized by weaknesses (holes in the slices of cheese). The greater portion of errors may penetrate one or two layers but are unlikely to penetrate all layers. The defenses fail when holes in defense layers inadvertently align and a path allowing the error to proceed to the accident is established. In this model the error rate is always higher than the accident rate (most errors don't make it all the way through to end in an accident). Thus, the supposed U.K. maintenance related accident rate of less than 6% was perceived as less than the estimated U.S. rate of 15% in the literature. The MORS error rate for aviation maintenance cannot be indicative of the actual rate of maintenance error since the maintenance error rate must be greater than the maintenance related accident rate in a sample, based on Reason's model. This assumption was not supported in the samples of this study. Although the U.S. sample accident rate (17%) was in rough agreement with the FAA-predicted rate of 15%, the U.K. sample rates were not comparable to the CAA-prediction.

While the CAA's 2007 analysis of MORS reports predicted a maintenance related accident rate below 6%, this dissertation research found a 21% maintenance related accident rate in the sample period after regulation came into force. The administrators of the MORS program require aircraft maintenance personnel to report errors, but also note that the CAA may revoke or suspend a mechanic's license or an operator's certificate, if the report indicates the holder of the license or certificate is unfit to continue in that capacity (CAA, 2005). The CAA acknowledges that this condition may make mechanics reluctant to self-identify or identify their fellow mechanics as offenders and may account for the much lower percentage of error reports found in the MORS system when compared to the accident rates in this study (CAA, 2005).

The supposition that the low MORS error rate indicated an even lower U.K. maintenance accident rate, when compared to the 15% estimates of the U.S. rate represented the formal problem for investigation and drove the research design of developing and comparing accident rates from accident records in each nation. Instead of the problem described by the literature, this study found no significant differences between U.S. and U.K. accident rates; the problem did not exist to any significant degree in the samples of this study.

Recommendations

Recommendations for practical application. Based on the literature review, an effect size of .25 (medium-small; Faul et al. 2009) was estimated for the study; the post hoc effect size was calculated as an average phi-coefficient of .087. While this agreement between effect size (small) and failure to reject the null hypotheses provides conclusion validity (Robinson & Levin, 1997), it also leads this dissertation researcher to recommend future researchers temper their expectations of the effect of regulations and estimate smaller effect sizes when preparing to compare other countries to U.K. performance.

The difficulties encountered in comparing different types of accident rates as well as the comparisons between U.S. and U.K. data contradicted the research problem derived from the literature. A universal system of classifying accidents with rigorous definitions and standards would more effectively highlight actual disparities among nations and time periods.

A strict interpretation of the results (in the absence of statistically significant changes the regulations were not effective) might lead readers to abandon efforts to implement regulations or discard regulations already in force. Within the U.K. population, the regulation may not be sufficiently effective, but the results also indicate the regulation did not have the opposite effect of increasing accident rates. Thus, the regulation did no harm. Consequently, this researcher cannot recommend abandoning U.K. human factor programs already in force.

The subset of equipment error and the prevalence of damage cause by ground handling crews raises questions over the training that ground handling crews receive and the resultant aircraft structural knowledge of the crews. In many cases, ground crews were unaware of the seriousness of the damage they had caused. As a practical application, ground handling crews may benefit from initial or more in-depth aircraft structural training.

Recommendations for future research. Future research might expand the ex post facto analysis to other industrialized countries possessed of human factors regulation while keeping the U.S. as a quasi-control group or baseline for comparison. The results of this dissertation research, the seeming in-tandem changes in U.S. and U.K. performance as well as the lack of significant difference between U.S. and U.K. performance seem to support the assumption of cultural similarity between the U.S. and U.K. It may also indicate the shared culture simultaneously renders attempts to alter organizational behavior on both sides of the Atlantic ineffective. This dissertation research was limited to the U.S. and U.K. in an attempt to improve the comparability of two groups in an ex post facto analysis. It did not reveal the expected relationship between human factors regulation and accidents. It may be that future research involving other cultures or an instrument other than the MEDA could provide more information on such a relationship.

This research relied on Hobbs' and Williamson's (2003) as well as Reason's (2004) direct link between human factors and human error and discounted intermediate variables based on the accepted theory in the literature of a direct link between the mandated human factors program and the maintenance related accident rate. Future research might instead focus on these intermediate variables. Similar to Reason's Swiss Cheese, Hobbs and Williamson described a chain of events and established a relationship between human factors and mechanic error (the two seemed to occur together). The authors could not, however establish that human factors actually caused the mechanic error. Further investigation into the links in this chain as well as the correlation between individual links in the chain may better explain the results of this dissertation research.

Research into how accident investigation and reporting methods may have been affected by the increased focus on maintenance error. Have the methods for investigating, identifying, and reporting causal maintenance factors changed over time?

Could this be confounding results such as those reported in this dissertation? Could a greater willingness to recognize maintenance error, in light of the increased focus on maintenance in the 2003-2008 period, attenuate the effect of regulation? During the 1990s, runway incursions (ground vehicles and other aircraft making unauthorized entries into the active runway) had become an item of increased FAA interest. Regulations were implemented to reduce the number of runway incursions, but seemed to have the opposite effect: runway incursions increased immediately. Researchers concluded that increased awareness of the problem caused pilots and air traffic controllers to report incursions that in the past went unnoticed. Aslanides et al. (2007) also observed an increase in human factor causes in French Air Force accident reports after accident investigators were given human factors awareness training. Even though this does not fully explain why the U.S. rate changed in a fashion so similar to the U.K. rate, it offers another avenue for research that might explain the disparity between the effect detected in this research and the common view in the literature.

Setting aside the question of the effectiveness of aviation regulation, the results of this study also shed more light on the theories of institutionalism, organizational evolution, and rational action elaborated on in Chapters 1 and 2. A review of Hackworth et al's. (2007) international survey indicated that organizations under the purview of regulations had indeed established formal human factors programs while those without similar oversight tended to implement fewer, informal (non-standardized) programs. In a sense, the behavior-change predicted by institutionalism did occur: organizations conformed to regulatory requirements and took the required actions to achieve compliance. The ultimate goal of regulation (a safer air transportation system) however, was not achieved in the particular case of this dissertation research. An investigation of regulation from an institutional perspective (using a broader data set than that of aviation accidents) might better illuminate the relationship between regulatory compliance and the institutional ecology sought by the regulator.

The issue of aircraft damage occurring on ramp warrants further investigation as 36% of all events discovered in the samples involved ground handling crew error. Like accident rates, this error-category remained unaffected by regulation; ground handling crew error appeared to be the cause of more aircraft damage than other categories of error. Future research might investigate the difference between the U.K. ground handling error rate and the much lower U.S. rate.

Conclusions

This dissertation research investigated the effect of human factors regulation on aviation maintenance organizations by examining U.S. and U.K. accident record to analyze changes in maintenance related accident rates. Through an ex post facto chi-square analysis, the research concluded that regulations had no significant effect on the U.K. accident rate in the periods covered by this dissertation study. Due to the ex post facto nature and the limitation of the research to two specific nations, generalization of the results to other nations and other time periods is not indicated and is left to the discretion of subsequent researchers.

In spite of the research limitations, this apparent rejection of the status quo in the literature (that the regulation would affect the rate) raised new questions as avenues of possible future study. At a higher level of theory, the outcome of the research also questions assumptions of positive regulatory effect found in the literature of institutionalism and organizational evolution.

Part of the difficulty of these results lies in the rejection of the accepted theory, and the common sense approach that a regulation must necessarily make things better. It was however, clear during the earlier stages of the literature review that the common sense, widely accepted theory was based primarily upon available opinion surveys and anecdotal evidence (interviews) in case studies. Like these surveys and interviews, this ex post facto, causal comparative analysis could not, under any circumstances, be used to demonstrate causality (or lack thereof) between regulation and accident. The research nevertheless calls into question the assumption of previous, survey and case-study research and may fine-tune future research efforts to possibly more fruitful lines of reasoning than this dissertation research.

The employment of an ex post facto causal-comparative analysis followed the pattern of research revealed in the literature review: case studies, followed by quantitative studies to link suspected steps in the process together, supported by surveys of management and mechanics led to the research design presented in this dissertation. Consequently, the exploratory objective was achieved in this research through findings that were previously unknown in the literature of the field by taking the next logical step of developing and comparing accident rates between nations and time periods.

This research took a two-fold approach to the single question of human factors regulation. Performance of an aviation system (U.K.) was examined before and after the implementation of a regulation and this performance was examined in reference to a third dataset (U.S.) where no regulation existed. This data triangulation offset the effects of confounding variables by comparing U.K. pre-and post-regulation results with a second comparison to U.S. data where no regulation exists. While the majority of the literature seems to support the implementation of JAR 145-style regulations, the case presented in this research is unique in its ex post facto accident rate analysis to determine the effect of a regulation. Through the unique approach of developing accident rates for nations and time periods for before-and-after comparisons, this research has further explored, but failed to confirm the phenomenon detected in previous survey-style research.

This dissertation research revealed some small but important information in light of Franco's (2008) dictum that the effectiveness of a particular program should be demonstrated before scarce financial organizational resources are committed to a scheme to improve aviation safety through some program of unproven effectiveness. Within the limitations of this research and based on the lack of statistical evidence of significance, human factors regulations were not sufficiently effective to warrant the investment of resources to implement human factors regulations for maintenance organizations.

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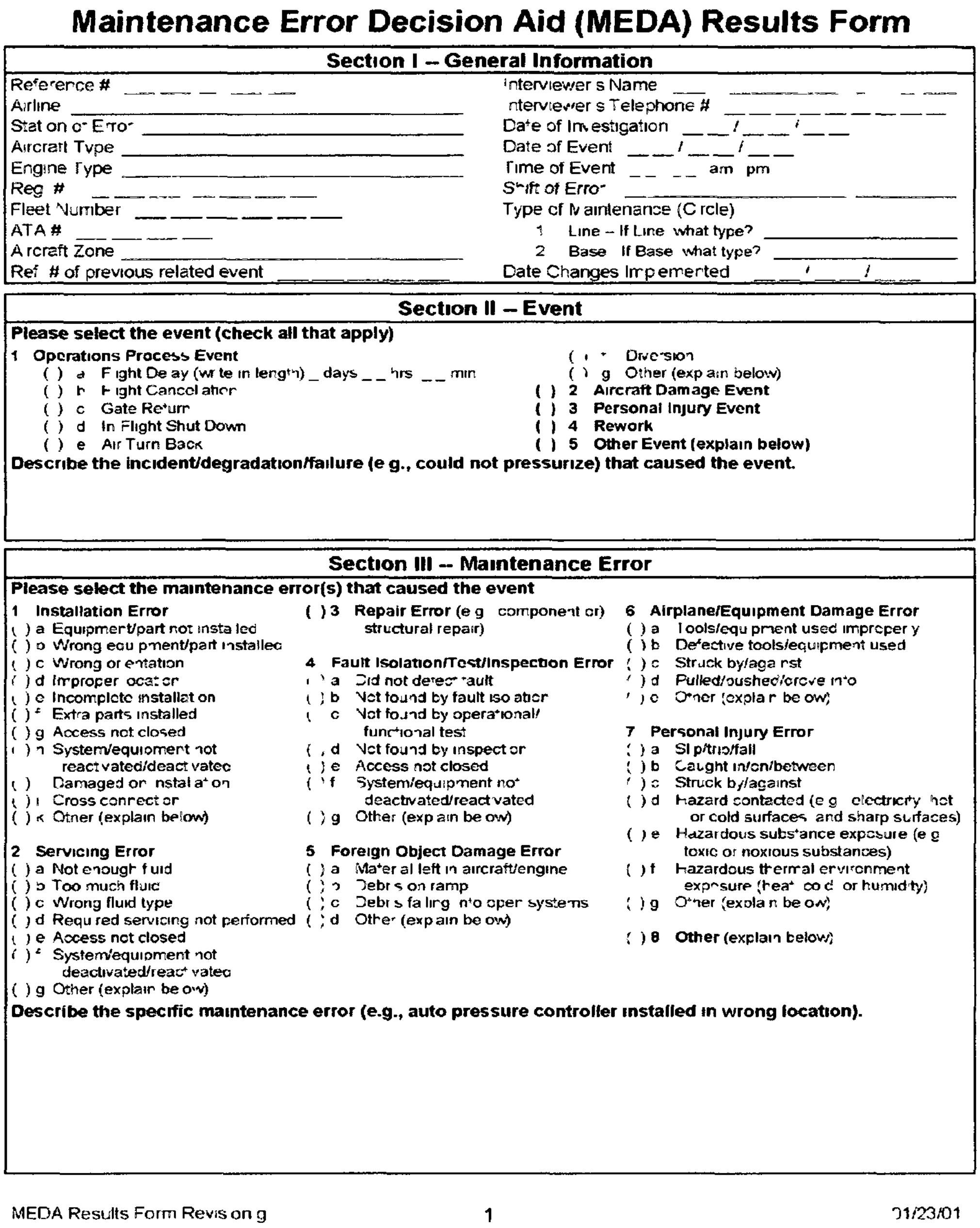
Appendices

Appendix A:

Maintenance Error Decision Aid



Maintenance Error Decision Aid (MEDA) Results Form

Section I – General Information

Reference # ___ ___ ___ ___ ___
Airline ________________
Station of Error ________________
Aircraft Type ________________
Engine Type ________________
Reg # ___ ___ ___ ___ ___
Fleet Number ___ ___ ___ ___ ___
ATA # ___ ___ ___ ___
Aircraft Zone ________________
Ref # of previous related event ________________

Interviewer's Name ________________
Interviewer's Telephone # ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Date of Investigation ___/___/___
Date of Event ___/___/___
Time of Event __ __ am pm
Shift of Error ________________
Type of Maintenance (Circle)
1 Line – If Line what type? ________________
2 Base If Base what type? ________________
Date Changes Implemented ___/___/___

Section II – Event

Please select the event (check all that apply)

1 Operations Process Event
( ) a Flight Delay (write in length) _ days _ _ hrs _ _ min
( ) b Flight Cancellation
( ) c Gate Return
( ) d In Flight Shut Down
( ) e Air Turn Back
( ) f Diversion
( ) g Other (explain below)
( ) 2 Aircraft Damage Event
( ) 3 Personal Injury Event
( ) 4 Rework
( ) 5 Other Event (explain below)

Describe the incident/degradation/failure (e.g., could not pressurize) that caused the event.

Section III -- Maintenance Error

Please select the maintenance error(s) that caused the event

1 Installation Error
( ) a Equipment/part not installed
( ) b Wrong equipment/part installed
( ) c Wrong orientation
( ) d Improper location
( ) e Incomplete installation
( ) f Extra parts installed
( ) g Access not closed
( ) h System/equipment not reactivated/deactivated
( ) i Damaged on installation
( ) j Cross connection
( ) k Other (explain below)

2 Servicing Error
( ) a Not enough fluid
( ) b Too much fluid
( ) c Wrong fluid type
( ) d Required servicing not performed
( ) e Access not closed
( ) f System/equipment not deactivated/reactivated
( ) g Other (explain below)

( ) 3 Repair Error (e.g. component or structural repair)

4 Fault Isolation/Test/Inspection Error
( ) a Did not detect fault
( ) b Not found by fault isolation
( ) c Not found by operational/functional test
( ) d Not found by inspection
( ) e Access not closed
( ) f System/equipment not deactivated/reactivated
( ) g Other (explain below)

5 Foreign Object Damage Error
( ) a Material left in aircraft/engine
( ) b Debris on ramp
( ) c Debris falling into open systems
( ) d Other (explain below)

6 Airplane/Equipment Damage Error
( ) a Tools/equipment used improperly
( ) b Defective tools/equipment used
( ) c Struck by/against
( ) d Pulled/pushed/drove into
( ) e Other (explain below)

7 Personal Injury Error
( ) a Slip/trip/fall
( ) b Caught in/on/between
( ) c Struck by/against
( ) d Hazard contacted (e.g. electricity, hot or cold surfaces, and sharp surfaces)
( ) e Hazardous substance exposure (e.g. toxic or noxious substances)
( ) f Hazardous thermal environment exposure (heat, cold, or humidity)
( ) g Other (explain below)

( ) 8 Other (explain below)

Describe the specific maintenance error (e.g., auto pressure controller installed in wrong location).

Section IV -- Contributing Factors Checklist

N/A __

A. Information (e.g., work cards, maintenance manuals, service bulletins, maintenance tips, non-routines. IPC, etc.)

__ 1 Not understandable
__ 2 Unavailable/inaccessible
__ 3 Incorrect
__ 4 Too much/conflicting information
__ 5 Update process is too long/complicated
__ 6 Incorrectly modified manufacturer's MM/SB
__ 7 Information not used
__ 8 Other (explain below)

Describe specifically how the selected information factor(s) contributed to the error.

N/A __

B.______ Equipment/Tools/Safety Equipment

__ 1 Unsafe
__ 2 Unreliable
__ 3 Layout of controls or displays
__ 4 Mis-calibrated
__ 5 Unavailable
__ 6 Inappropriate for the task
__ 7 Cannot use in intended environment
__ 8 No instructions
__ 9 Too complicated
__ 10 Incorrectly labeled
__ 11 Not used
__ 12 Incorrectly used
__ 13 Other (explain below)

Describe specifically how selected equipment/tools/safety equipment factor(s) contributed to the error.

N/A __

C.______ Aircraft Design/Configuration/Parts

__ 1 Complex
__ 2 Inaccessible
3 Aircraft configuration variability
__ 4 Parts unavailable
__ 5 Parts incorrectly labeled
__ 6 Easy to install incorrectly
__ 7 Other (explain below)

Describe specifically how the selected aircraft design/configuration/parts factor(s) contributed to error.

N/A __

D.______________________Job/Task

__ 1 Repetitive/monotonous
__ 2 Complex/confusing
__ 3 New task or task change
__ 4 Different from other similar tasks
__ 5 Other (explain below)

Describe specifically how the selected job/task factor(s) contributed to the error.

N/A __

E.__________Technical Knowledge/Skills

__ 1 Skills
__ 2 Task knowledge
__ 3 Task planning
__ 4 Airline process knowledge
__ 5 Aircraft system knowledge
__ 6 Other (explain below)

Describe specifically how the selected technical knowledge/skills factor(s) contributed to the error.

N/A __

F. Individual Factors

__ 1 Physical health (including hearing and sight)
__ 2 Fatigue
__ 3 Time constraints
__ 4 Peer pressure
__ 5 Complacency
__ 6 Body size/strength
__ 7 *Personal event (e.g., family problem, car accident)*
__ 8 Workplace distractions/interruptions during task performance
__ 9 Memory lapse (forgot)
__ 10 Other (explain below)

Describe specifically how the selected <u>factors affecting individual performance</u> contributed to the error.

N/A __

G. Environment/Facilities

__ 1 High noise levels
__ 2 Hot
__ 3 Cold
__ 4 Humidity
__ 5 Rain
__ 6 Snow
__ 7 *Lighting*
__ 8 Wind
__ 9 Vibrations
__ 10 Cleanliness
__ 11 *Hazardous/toxic substances*
__ 12 Power sources
__ 13 Inadequate ventilation
__ 14 Other (explain below)

Describe specifically how the selected <u>environment/facilities</u> factor(s) contributed to the error.

N/A __

H. Organizational Factors

__ 1 Quality of support from technical organizations (e.g., engineering, planning, technical pubs)
__ 2 Company policies
__ 3 *Not enough staff*
__ 4 Corporate change/restructuring
__ 5 Union action
__ 6 Work process/procedure
__ 7 Work process/procedure not followed
__ 8 Work process/procedure not documented
__ 9 *Work group normal practice (norm)*
__ 10 Other (explain below)

Describe specifically how the selected <u>organizational factor(s)</u> contributed to the error.

N/A __

I. Leadership/Supervision

__ 1 Planning/organization of tasks
__ 2 Prioritization of work
__ 3 Delegation/assignment of task
__ 4 Unrealistic attitude/expectations
__ 5 Amount of supervision
__ 6 Other (explain below)

Describe specifically how the selected <u>leadership/supervision</u> factor(s) contributed to the error.

N/A __

J. Communication

__ 1 Between departments
__ 2 Between mechanics
__ 3 Between shifts
__ 4 Between maintenance crew and lead
__ 5 Between lead and management
__ 6 Between flight crew and maintenance
__ 7 Other (explain below)

Describe specifically how the selected <u>communication</u> factor(s) contributed to the error.

N/A __

K. Other Contributing Factors (explain below)

Describe specifically how this <u>other factor</u> contributed to the error.

Section V – Error Prevention Strategies

A. What current existing procedures, processes, and/or policies in your organization are intended to prevent the incident, but didn't?

( ) **Maintenance Policies or Processes** (specify) ____
( ) **Inspection or Functional Check** (specify) ____

Required Maintenance Documentation

( ) Maintenance manuals (specify) ____
( ) Logbooks (specify) ____
( ) Work cards (specify) ____
( ) Engineering documents (specify) ____
( ) Other (specify) ____

Supporting Documentation

( ) Service Bulletins (specify) ____
( ) Training materials (specify) ____
( ) All-operator letters (specify) ____
( ) Inter-company bulletins (specify) ____
( ) Other (specify) ____

( ) **Other** (specify)

B. List recommendations for error prevention strategies.

Recommendation #	Contributing Factor #	

(Use additional pages, as necessary)

Section VI – Summary of Contributing Factors, Error, and Event

Provide a brief summary of the event.

(Use additional pages, as necessary)

Appendix B:

U.K. 1995-2000 Sample

Report Information		150	Maintenance			Error Category						
		Sample	0 27	0 73		0 27	0	0 16	0 27	0 08	0 54	
		138	37	101	12	10	0	6	10	3	20	
ID	Title	Date	Yes	No	Discards	Installation	Servicing	Repair	Inspection	Foreign Object	Equipment	Remarks
290	Cessna 340, G-KINK, 30 May 1996	30-May-96		x								Pilot fuel starvation engine shutdown in flight
169	Boeing 737-59D, G-OBMX	22-Oct-00		x								During taxi, marshaller signaled stop, aircraft contacted structure, pilot distracted
363	Fokker F28 Mark 100, G-UKFR	1-May-99		x								Manufacture defect, burnt-out RAM chip in primary flight display, electrical fire, IFE
243	Boeing 757-236, G-BIKH	22-Oct-98	x								x	Baggage loader failed to stop, impacted aircraft
370	HS 748 Series 2A, G-BVOV	29-Sep-95		x								One man ground crew during launch, pilot taxied without marshaller
384	Jetstream 4100, G-MAJI	1-May-98	x			x			x	x		Incorrect electrical connection of engine generator started fire, rag left in cowling, no certification, incorrect inspection
161	Boeing 737-500, G-BVZF	12-Aug-95	x								x	Catering truck struck aircraft
49	Airbus A340-311, G-VAEL	14-Dec-96		x								IFE for lost hydraulic fluid, leak from brake system, flexible hose manufacturer

												marked wrong part number on hose
309	DHC-8-311, G-BRYK, 16 May 1997	16-May-97	x			x						Ac duct installed incorrectly, came apart, singed insulation, burning smell in pax compartment
346	Fokker F27 Mark 500, G-CEXA, 6 May 1997	6-May-97		x								Hard landing on nose gear
102	BN2B-26 Islander, G-BLDV	8-Mar-00	x			x			x			Engine cylinder hold down nuts not properly torqued
260	Boeing 757-2T7, G-MONE	24-Jan-00	x					x	x			Poor work practice during LG actuator overhaul, actuator failure 11 years later
227	Boeing 747-436, G-BNLZ, 13 February 1996	13-Feb-96		x								Pilot on medication, had "fit" in flight
288	Cessna 310R, G-FISH	11-Nov-95		x								Pilot lost control on slippery grass surface during landing
85	BAe ATP, G-BTTO	12-Nov-95	x								x	Ground crew fail to remove GPU during launch, signalled pilot to taxi, aircraft struck GPU
380	Jetstream 4100, G-MAJA	18-Jan-98		x								Lightning strike
56	BAC One Eleven 401AK, G-BBME	23-Oct-96		x								Apu fire during launch, corrosion related air leak, fuel control defective
31	Airbus A320-212, G-DACR, 28 April 1996	28-Apr-96		x						x		FOD cracked windscreen, no maintenance involved
302	DH104 Dove 8, G-ARHW	12-Dec-99		x								Flare too high, tire and LG failure
183	Boeing 747-136, G-AWNF	22-Aug-99		x								Galley drain leak, ice seized aileron control cables
152	Boeing 737-436, G-DOCV	10-Jun-96		x								Tire met FOD on takeoff
121	Boeing 737-204 ADV, G-SBEB	13-Aug-98	x						x			Door failure during overpressurization, cracks not detected during tech order specified inspection of area

137	Boeing 737-3Q8, G-OBML, 1 November 1996	1-Nov-96	x					x	x			During overhaul, engine LPT shaft stripped with corrosive non-tech order material, subsequent corrosion and shaft failure
188	Boeing 747-136, G-BBPU	8-Feb-98		x								Copilot inadvertant emergency gear retract, damaged LG bay
168	Boeing 737-59D, G-BVZF	4-Apr-97	x								x	Tug driver inavertantly hit accelerator with tow bar attached, towbar failure, no damage on aircraft
457	Westland Scout, G-BXRL	16-Oct-99			x							Helicopter-discard
26	Airbus A300-600, A6-EKF and Boeing 747-436, G-BNLM Corrigendum	15-Apr-96			x							Report correction-discard
122	Boeing 737-229, G-CEAD, 17 October 2000	17-Oct-00		x								Birdstrike
134	Boeing 737-33V, G-EZYH	30-Oct-00		x								Cross winds, tailstrike on takeoff
366	Fokker F28-70, G-BVTG, 15 July 1996	15-Jul-96	x								x	Catering truck impacts aircraft during servicing
250	Boeing 757-236, G-BIKU	9-Sep-98	x								x	Tug cab struck aircraft
433	SD3-60 Variant 100, G-BKMX	1-Mar-97		x								Pilot lost control at touchdown
454	Spitfire Tr 9, G-TRIX	8-Apr-00		x								Pilot fatigue/medications
174	Boeing 737-5Q8, G-BVZH	31-Aug-00	x								x	Cargo vehicle struck aircraft, ground personnel distrated by other vehicle
119	Beechcraft Duke, G-IASL	9-Jun-97	x					x				LG mechanism unpainted areas were painted, LG failed to extend
216	Boeing 747-436, G-BNLD	18-May-97	x								x	Conveyor belt vehicle struck aircraft
255	Boeing 757-236, G-BPEE Corrigendum	28-Jul-98			x							Correction report discard

239	Boeing 757-236, G-BIKD	22-Jul-98	x								x	Conveyor belt vehicle struck aircraft
43	Airbus A320-231, G-VCED Corrigendum	20-Jan-00			x							Correction report-discard
175	Boeing 737-5Q8, G-BVZI	19-Aug-97	x								x	Baggage tug struck aircraft
150	Boeing 737-436, G-DOCR, 26 June 1996	26-Jun-96		x								Cabin pressure controller failed-no maintenance error
349	Fokker F27 Mark 500, G-JEAE, 17 December 1998 at 1448 hrs	17-Dec-98		x								First officer inadvertant brake application while trying to control aircraft during rollout
357	Fokker F28 Mark 0100, G-BVJC	10-Nov-95		x								MLG wheel/tire struck taxiway edge lights in fog
145	Boeing 737-436, G-DOCG	18-Jan-95		x								Aircraft skin damage near cargo door (no witnesses-not reported)
267	Boeing 767-336, G-BNWL, 20 November 1996	20-Nov-96			x							Invalid report number
425	Piper PA-38-112, G-BGSI	16-Dec-00		x								Pilot lost control during touchdown
276	Boeing B757-204, G-BYAN and McDonnell Douglas F15E	22-Nov-00		x								ATC near mis 757/ F-15
48	Airbus A340-311, G-VAEL	30-Apr-95		x								Ice fell from potable water servicing port-leak
332	Fokker 100, G-UKFF, 7 April 1996	7-Apr-96		x								Crew physiology incident-ccause unknown
344	Fokker F27 Mark 500, G-BVOM, 11 August 1996	11-Aug-96		x								Too slow on approach tailstrike
74	BAe 146-300, G-BPNT	17-Feb-97		x								Pilot opened electronic bay access, first officer fell through opening
257	Boeing 757-236,G-BIKC	12-Oct-97		x								Aircraft suddenly pitched up on touchdown
38	Airbus A320-231, G-OOAC	26-May-97		x								Brake disc failed on takeoff-debris on runway-no maintenance error

398	North American T-6 Harvard 2A Texan, G-TEAC	4-Mar-95		x								Pilot lost control-spin
262	Boeing 767-204, G-BRIF	18-Aug-98		x								Pilot neurological illness
277	Bolkow BO-105DBS-4, G-NAAA	25-Jul-00			x							Helicopter
314	Dart Herald 401, G-BEYF	13-Aug-98		x								Engine fireloop failure-false alarm engine fire- no maintenance error
447	Shorts SD3-60 100 series, G-OLAH and Tornado F3 Corrigendum	20-Mar-00			x							Correction report discard
224	Boeing 747-436, G-BNLM and Airbus A300-600, A6-EKF, 15 April 1996	15-Apr-96		x								Missed approach near miss with other traffic
46	Airbus A321-231, G-MIDA, 14 August 1998	14-Aug-98	x						x			Cabin pressure fail from tailstrike damage-not detected during maintenance inspection
327	Embraer EMB-110 P1 Bandeirante, G-OCSZ	24-Aug-95		x								Generator control unit failed, no maintenance error
358	Fokker F28 Mark 0100, G-BYDN Addendum	3-Nov-00			x							Correction report discard
12	3/2001 HS748 Series 2B, G-OJEM	30-Mar-98		x								Manufacturer defect caused HP turbine failure
212	Boeing 747-283B, G-VOYG, 6 August 1996	6-Aug-96	x			x						Lost engine cowling, latches not properly engaged
172	Boeing 737-5L9, G-MSKA	14-Apr-98		x								Manufacturer defect caused galley oven fire
378	Jetstream 3200, G-OAKJ	29-Jan-96		x								Hit deer on takeoff
381	Jetstream 4100, G-MAJA, 5 January 2000	5-Jan-00		x								Manufacterer defect GPU fire
286	Cessna 310Q, G-TVMM, 19 July 1996	19-Jul-96		x								Hard landing
213	Boeing 747-436 G-BNLA	24-Feb-98		x								Elevator damage unknown cause

191	Boeing 747-236B, G-BDXA	12-Oct-97	x			x						Lost wing fillet panel after improper attempt to secure panel with sealant
11	3/1999 Boeing 757-200, G-WJAN	1-Jan-98		x								CRM pilot error
101	BN2B-26 Islander, G-BLDV	3-Jun-99		x								Icing
348	Fokker F27 Mark 500, G-JEAE	29-Jun-00		x								Throttle jam, possible pilot applying side loads to levers
73	BAe 146-200, G-OWLD	29-May-97		x								Engine fire false alarm caused by switch shorting out
437	Saab-Scania SF340A, G-GNTE	15-Jul-99		x								Manufacterer defect, gas gen turbine failure, engine damage, engine failure
218	Boeing 747-436, G-BNLE, 14 January 1996	14-Jan-96		x								Pilot error, loss of SA
114	Beech E55 Baron, G-BFEE, 8 July 1996	8-Jul-96		x								Pilot error failed to select correct fuel tank
280	Cessna 310K, G-OBNF	21-Aug-00		x								Grass runway insufficient braking retardation, overrun area had been ploughed up (by farmer?)
14	4/1999 Fokker F27-500, G-BNCY	7-Dec-97		x								Crosswind, landed long, lost control, pilot error
406	Piper PA-23-250, G-BATX	18-Dec-98		x								MLG failed to lock down, cause unknown
19	ATR42-300, G-ORFH	5-Feb-00	x			x			x			Cowling not secured after maintenance powerplant checks performed night before flight, DO
452	Spitfire IXT, G-TRIX	15-Sep-96		x								LG collapse, metal fatigue
416	Piper PA-30 Twin Commanche, G-AXRO	5-Jul-00		x								Water in fuel, loss of power, loss of control
190	Boeing 747-200, G-BDXA, 23 May 1996	23-May-96	x			x		x				Improper length fasteners after structure beef-up repair, panel broke away in flight, DO

369	HS 748 2B, G-EMRD	22-Feb-97	x								x	Marshaller cleared AC to taxi, struck another aircraft
211	Boeing 747-243B, G-VGIN	28-Apr-97	x			x						Poor electrical work practice, damaged insulation consistent with wire being pulled through p-clip, short, fire
409	Piper PA-23-250, G-BGTG, 5 September 2000	5-Sep-00		x								LG did not extend, no defect in LG system
373	Hawker Hunter Mk 58A, G-PSST	20-Jun-99		x								Windshear as pilot flared for landing, tailstrike
184	Boeing 747-136, G-AWNG	27-May-97	x						x			Overhaul failed to use flouro dye penetrant inspection to detect extant crack in combustion chamber casing, engine failure
39	Airbus A320-231, G-OOAC Addendum	26-May-97			x							Addendum discard
157	Boeing 737-4S3, G-BUHL, 16 April 1996	16-Apr-96	x								x	Damage to aircraft from stair truck jacks
5	1/2001 Boeing 747-436, G-BNLY and Airbus A321, G-MIDF	28-Apr-00		x								ATC trainer/trainee near miss
451	Spitfire IXT, G-LFIX	31-Mar-00		x								Taxi collision spitfire
427	Reims Cessna F406 Caravan II, G-SFPA	25-Nov-97		x								Birdstrike
64	BAe 146, G-ZAPK, 18 November 1996	18-Nov-96		x								Spoiler failed to deploy, unknown cause
94	BAe ATP, G-MANU	3-Jul-98		x								Prop spinner bolts loose, SB issued
456	Viscount 836, G-BFZL, 22 March 1996	22-Mar-96		x								Poor visibility during taxi, aircraft departed paved surface
201	Boeing 747-236B, G-BDXK	2-Nov-96	x			x		x				Rollercrank attach holes in torque tube for pax door incorrectly drilled, door opens in flight
444	Shorts 360-100, G-OLAH	9-Oct-96		x								Student pilot hard brake (before touchdown?)

106	BN2T Islander, G-WOTG	12-Jun-97		x								Parachutist's aircraft sliding door DO, (may have been opened at excessive airspeed?)
371	Hawker Hunter F 4, G-HHUN	5-Jun-98		x								Turbine engine overfueling heat failure, unknown cause (inexperience pilot had valve in isolate with throttles still open?)
154	Boeing 737-46B, G-OBMN, 5 April 1996	5-Apr-96		x								Pilot incapacitated (unconcious and vomiting)
441	Saab-Scania SF340B, G-GNTH	27-Feb-98		x								Crosswind takeoff, loss of control (NW castor may have been OOL?)
166	Boeing 737-59D, G-BVKA	6-Aug-96		x								APU failure, trubine wheel hub ejected from exhaust, unknown cause
403	Piper PA-23-250 Aztec, G-RVRC	26-May-98		x								NLG fork fratured, unknown cause
237	Boeing 757-236, G-BIKB, 13 July 1996	13-Jul-96	x								x	Trainee tug driver struck aircraft
71	BAe 146-200, G-JEAS, 19 May 1996	19-May-96	x								x	Marshaller cleared aircraft to taxi, aircraft directly behind, prop balst moved stairs personnel fell and injured
450	Spitfire IXT, G-BMSB	25-Apr-98	x					x		x		FOD after MOD blocked full throw of gear lever, gear not locked down
362	Fokker F28 Mark 070, G-BVTF	23-Apr-99	x								x	Baggage truck struck aircraft
107	Beagle B206 Series I Bassett, G-BSET	2-Sep-95		x								LG uplock failed to relase, manual override not used, (pilot may not have had three "down and locked" indications?), unknown cause
203	Boeing 747-236B, G-BDXL	30-Aug-99		x								AC pac duct fail cause unknown
215	Boeing 747-436, G-BNLB	25-Feb-00		x								Pitch oscillations in AP caused by ice binding cables

303	DH112 Venom FB50, G-VIDI, 7 July 1996	7-Jul-96		x								Pilot error, rotated with insufficient airspeed, wing dropped after lift off
32	Airbus A320-212, G-HAGT	25-Jul-95	x			x			x			Emergency slide cover panel not reinstalled (left unsecured on wing) DO
123	Boeing 737-236, G-BGDI	6-May-98	x						x			Maintenance failed to use proper insp technique, exterior visual instead of NDI, cracks undetected before structural failure
334	Fokker 50, G-UKTH, 4 April 1996	4-Apr-96		x								Aircraft cleared to land while runway lighting maintenance in progress
192	Boeing 747-236B, G-BDXA and Boeing 747-436, G-BNLA	17-Mar-95		x								Tow bar broke, electrical disconnect powering hyd pump left one brake application of pressure Brake rider stopped aircraft but slope and wind drove aircraft to strike another parked aircraft Standard tow practices were followed- crew attrempted to stop ac w/chocks but failed
445	Shorts SD3-30 Variant 100, G-ZAPC	3-Jan-97		x								Approach speed low, stall, hard landing, unknown cause
247	Boeing 757-236, G-BIKL	10-Oct-00		x								Lightning strike
33	Airbus A320-212, G-JDFW, 10 July 1996	10-Jul-96		x								MLG tires failed on takeoff, LG and engine damage
83	BAe ATP, G-BTPD Corrigendum	22-Feb-95			x							Correction discard
118	Beechcraft Baron 58, G-BAHN	11-Aug-95		x								Pilot inadvertantly pulled mixture levers back instead of intended prop control lever
266	Boeing 767-336, G-BNWF	1-May-98		x								Brake reaction rod failed, brake failure, cause unknown
273	Boeing 767-336, G-BNWY, 3 September 1996	3-Sep-96		x							x	Fuel truck driver drove away while connected to aircraft

317	De Havilland Canada DHC-8-311, G-BRYS	29-Sep-98		x								ATC, pilot unaware autopilot engaged
399	North American T-6G Harvard, G-BKRA	14-Mar-00		x								Groundlooped during taxi out
361	Fokker F28 Mark 0100, G-UKFK	13-Oct-97		x								Lightning strike
69	BAe 146-200, G-JEAS	17-Jun-98	x								x	Baggage trolly struck aircraft
81	BAe ATP, G-BTPD	22-Feb-95	x								x	Baggage trolly struck aircraft
411	Piper PA-23-250, G-KEYS	3-Nov-99		x								Prop hit unlit temp taxiway edge light
117	Beech Super King Air 200, G-OLDZ	11-Jul-98		x								Burnt out vent blower motor, fumes in cockpit
400	P84 Jet Provost T MK4, G-TOMG	1-Aug-99		x								Lost control during low alt low AS maneuver
389	Lockheed L1011-385-1-14 Tristar, G-BBAH	31-Oct-96			x							Helicopter report mimarked as Lion
390	Lockheed L1011-385-1-14, G-BBAF	19-Jul-98		x								Windshear, high sink rate on final, hard landing, stall warning false alarms
220	Boeing 747-436, G-BNLF	4-Apr-97		x								Windshear, high sink rate on final, hard landing, stall warning false alarms
116	Beech Super King Air 200, G-BVMA	25-Jan-97		x								Door blew out in flight, hook/clevis pin failure, hook replaced last overhaul uncertain if clevis required replacement
1	1/1997 Douglas Aircraft Company MD-83, G-DEVR	27-Apr-95		x								MLG failure from cracking fatigue condsidered undetectable by approved insopection method
179	Boeing 747-136, G-AWNB	4-Oct-95		x								Jetty hoist fault damaged aircraft
377	Jetstream 31, G-LOVA	30-Jun-98		x								Worn NLG steering valve resulted in uncommanded left steer input on condition item,

												approved inspection would not detect problem
347	Fokker F27 Mark 500, G-JEAD, 28 January 1999 at 0054 hrs	28-Jan-99	x								x	Follow me truck took inappropriate route that allowed AC MLG to stray off paved surface
448	Special Bulletin S1/99 G-ILGW	3-Sep-99			x							Special bulletin-discard
128	Boeing 737-236, G-BKYI	8-Nov-96		x								Wake vortex
103	BN2B-26 Islander, G-BLDV	18-Mar-00		x								Engine crankshaft failed, not renitrited, shaft may have been swapped from another engine, records did not exist
353	Fokker F27 Mk 500 Friendship, G-JEAH, 4 August 1995	4-Aug-95		x								34 deg hub switch excessive wear caused picth hang up as cruise lock would not disengage, HPC left open
442	Saab-Scania SF34DA, G-GNTB, 1 May 1996	1-May-96	x								x	GPU struck aircraft
143	Boeing 737-436, G-DOCD, 17 May 1998 at 1020 hrs	17-May-98		x								Aircraft taxied into truck while using AGNIS system
245	Boeing 757-236, G-BIKK	23-Sep-97		x								Hyd lea from truck tilt actuator resulted in insufficient pressure to lock gear door cloed, cockpit warning light
391	Lockheed L188C, G-LOFA	30-Jul-96		x								Cargo door not fully latched on departure, bolts failed during climb
359	Fokker F28 Mark 0100, G-BYDN, 3 November 2000 at 1945 hrs	3-Nov-00		x								Elevator movement restricted by possible icing, cleared by forced movement of elevators, crew deselected AP 1 but inadvertantly selected AP 2 which took control until manual trim input automatically disengaged autopilot

187	Boeing 747-136, G-AWNO, 8 February 1996	8-Feb-96		x								Switch in attendants control panel shorted, parts disposed of before AAIB examination

Appendix C:

U.K. 2003-2008 Sample

Report Information			Maintenance			Error Category						
		Sample	0.21	0.79		0.24	0.14	0.14	0.24	0.03	0.55	
		138	29	109	13	7	4	4	7	1	16	
ID	Title	Date	Yes	No	Discards	Installation	Servicing	Repair	Inspection	Foreign Object	Equipment	Remarks
232	Lockheed L188C Electra, G-FIJV	12-Oct-06		x								Starter motor casing failed, deformed engine cowling, cowling departed AC, on-condition item no inspection required
21	Airbus A320-231, G-MEDA Addendum	31-Mar-03			x							Incorrect bearing information from Addis Abeba VOR, Ethioopia, addendum to report in thos sample, discard
224	Interim Report - Boeing 777-236ER, G-YMMM	17-Jan-08			x							Ice formed in fuel system causing restriction, engine reduced EPR, covered in another repot in the sample-discard
37	Airbus A321-231, G-OZBN	28-Aug-07		x								Tire tread separated on landing
169	Cessna 560XL Citation XLS, G-OROO	29-Jun-08	x			x			x			Mechanic interrupted during engine cowling installation, panel tacked on, subsequent panel check failed to identify unsecured panel
17	Airbus A319-131, G-DBCI - Re-issued Bulletin	18-Apr-07			x							Bulletin-dicard

	Report											
66	BAe 146-300, G-JEBA	2-Feb-06		x								Pilot physiology incident, unknown cause
228	Jetstream 4100, G-MAJA	29-Jun-05		x								Aircraft overloaded, inflight AP oscilations, loss of control on landing
167	Cessna 550 Citation, G-FCDB	25-Nov-04		x								Aircraft did not line up on centerline for takepff, struck rabbit and departed paved surface
199	Dassault-Breguet Mystère-Falcon 900B, G-HMEV	20-Jan-07		x								Manufacturer defect caused LP turbine failure uncontained
74	BAe ATP, G-MANE	10-Feb-03		x								Unknown mist/odor in cabin
104	Boeing 747-436, G-BNLG	21-Apr-04	x								x	Airbrige incorrect position, aircraft struck airbridge during parking maneuver
249	S2/2005 Airbus A319-131, G-EUOB	22-Oct-05			x							Bulletin-discard
190	DHC-8-311, G-WOWA	31-Dec-06		x								Downdraft, loss of airspeed on approach, tailstrike
45	Airbus A340-642, G-VSHY	25-Feb-06		x								Crosswind landing touchdown at runway edge, tire damage
6	Aero L-39C Albatros, G-OALB	10-Dec-04			x							
25	Airbus A320-232, G-EUUI	29-Nov-03		x								Cracked temp prop false readings, engine surges in flight
237	Piper PA-31 Navajo, G-ILEA	18-May-03		x								Ran out of fuel over ocean, aircraft not recovered
264	Short Brothers SD3-60 Variant 100, G-VBAC	4-Mar-04		x								Engine multiple fail to start, pool of oil, possible flame, subsequent engine operation normal

155	British Aerospace Jetstream 4102, G-MAJZ	26-Jun-07	x								x	During push back, pilot decided to return to stand, NLG collapsed when maintenacne tried to return AC to stand, no headsets (OI requires headsets communication between ground and aircrew during pushback), parking AC parking brake engaged
222	Hawker Hunter Mk 58A, G-PSST	30-May-04		x								Tailplane interconnect engaged (for higher maneuverability in flight), tailstrike on landing
214	Embraer EMB-145EU, G-EMBE and two McDonnell Douglas F15E Eagle Aircraft	27-Jan-05		x								Near miss with F-15s
161	Cessna 310L, G-AZUY	29-Sep-03		x								Stuck relay overdrove MLG cycle, broke downlock and started retraction cycle on landing
159	Cessna 208 Caravan I amphibious floatplane , G-MDJE Re-issued Bulletin	24-May-08		x								Amphib rudder damage caused by rudder striking sumerged object
98	Boeing 737-73V, G-EZKA	28-Mar-05		x								Possible deicing fluid in APU intake, smoke in cockpit
200	De Havilland Canada DHC-8 Series 311, G-NVSB	9-Aug-05		x								Failed prop blade bearing, prop could not feather after shutdown
111	Boeing 747-443, G-VROM	8-Oct-06		x								Low on fuel landing (below minimum reserve) pilot called MAYDAY
42	Airbus A340-313, G-VAIR	27-Apr-08		x								Loss of visual reference during landing, grew called go around, but touched down briefly with MLG off the runway

61	BAe 146-200, G-JEAW	7-Dec-05		x								Deicing fluid in APU intake, intake susceptible to fluid streaming down fuselage in to intake
261	Saab-Scania SF340A, G-RUNG	28-Dec-04		x								Insufficient NW steering authority caused aircraft to miss turn off of runway after landing (system not recovered from excessive brake applications?)
254	SC7 Skyvan 3A Variant 100, G-PIGY	22-Jan-03		x								Manufacturer defect, incomplete paint treatment in bore of LG strut, corrosion fracture failure
208	Embraer EMB-145EP, G-EMBD	15-Nov-03		x								Manufacturer defect, leaking wheel overpressure valve, uderinflated tire failure
138	Boeing 777-236, G-VIIO	16-Aug-04		x								Turbulence and onb board injury
270	Special Bulletin S9/2006 Airbus A319-111,G-EZAC	15-Sep-06		x								Manufacturer defect inadequate logic in GCU disconnected APU from bus, APU was subbed for defective no 1 bus tie connecting No 1 generator
43	Airbus A340-642, G-VATL	8-Feb-05			x							Interim report discard
137	Boeing 777-236, G-VIIL	6-Aug-03		x								Refuel hose detached during refuel (as refuel finished)
149	Bombardier DHC-8-402 Dash 8, G-JEDO	23-Feb-06	x								x	Deicing vehicle struck aircraft
206	Embraer 145EU, G-EMBP	5-Aug-05		x								Fan bearing failed, smoke in cabin
275	Summary of AAR 2/2006 Pilatus Britten-Norman BN2B-26 Islander, G-BOMG	15-Mar-05		x								CFIT pilot fatigue, workload and experience contributing factors

191	DHC-8-311, G-WOWD	13-Dec-06		x								Bearing failure, wheel departed AC on takeoff
120	Boeing 757-236, G-CPET	4-Oct-06		x								Oil leak, fumes in cockpit
238	Piper PA-31-350 Navajo Chieftain, G-BBNT	16-Aug-06		x								Vehicle entered overun from public road, runway incursion
246	S1/2008 - Boeing 777-236 ER, G-YMMM	17-Jan-08	x							x		Maintenance debris found in fuel tanks, may not be related to autothrottle incorrect signal on approach, short landing, damage, NLG and MLG
145	Boeing 777-240(LR) and DHC-8-402 Dash 8, AP-BGY and G-JEDR	15-Feb-07		x								Ground collision, aircraft trying to pass another
24	Airbus A320-232, G-EUUF	26-Jun-06		x								Tractor operator gave all clear to aircrew before repositioning tractor, aircraft collided with tractor on taxi
236	Piper PA-23-250 Aztec, G-BGTG	18-Jul-07		x								Manufacturer defect, insufficient anodic coating of gear door actuator, corrosion stress failure
26	Airbus A320-232, G-EUUR	26-Nov-08		x								ATC-pilot descended below MSA
13	Airbus A319-111, G-EZIU	6-Feb-07		x								Numerour false alarm cautions and warnings, intermittant caution panel fault
141	Boeing 777-236, G-YMME	3-Jul-03		x								Clear air turbulence
177	Concorde Type 1 V102, G-BOAC	13-Jun-03	x									FQ wiring short in bay with fuel leak caused small fire, chafed wire may have been result of earlier maintennce (2 years earlier)

153	British Aerospace HS 748 Series 2A, G-BGMN	12-Nov-03		x								Runway conflict, two aircraft taxiing
93	Boeing 737-59D, G-BVKC	21-Feb-04	x						x			Inadequate maintenance and ispection of torque arms resulted in MLG shimmy and torque arm failure
90	Boeing 737-436, G-DOCL	15-Jun-03		x								Retread tire treard separation, specific cause unknown
119	Boeing 757-236, G-CPES	19-Nov-03	x				x					Engine oil serviced overfull, fumes in cockpit
176	Cessna T310R, G-VDIR	4-Sep-05		x								LG collapsed, cause unknown
86	Boeing 737-36Q, G-THOJ	13-Aug-06		x								DC battery bus fail
125	Boeing 757-2T7, G-MONK	13-Dec-08		x								Autopilot on approach, stick shaker, did not engage localizer cap, missed approach, autothrottle and autoplilot disengaged with speedbrakes out Confusion in cockpit and demanding weather
263	Short Brothers SD3-60 Variant 100, G-VBAC	20-Apr-04	x					x				Crew escape hatch departed aircraft in flight, earlier (five flights) aircraft used for evacuation training, instructor (pilot could not reclose hatch and notified ground staff (not a mechanic), ground staf failed to investigate
83	Boeing 737-33V, G-EZKA Correction	28-Dec-05			x							Correction to G-ezka in this sample, no additional information, discard
123	Boeing 757-2T7, G-MONB	13-Nov-03		x								Flight attendant slipped, injured

121	Boeing 757-236, G-CPET	10-Mar-06		x								Fumes in cockpit, minor engine oil leak
207	Embraer E120 Brazilia, F-GFEO	31-Mar-05		x								Trainee pilot error purposely not corrected by trainerresulted in descent below minimum
117	Boeing 757-236, G-BMRE	30-Jul-05	x			x		x	x			Brake torque rod not reattached
19	Airbus A319-131, G-EUPF	30-Oct-05		x								Manufacturer defect avionic systenm vent fan, burning smell in aircraft
277	Summary AAR 2/2008 Airbus A319-131, G-EUOB	22-Oct-05		x								Aircraft design defect no redundant power for instruments, electrical failure resulted in total instrument and lighting failure inflight
162	Cessna 404 Titan, G-OOSI	16-Dec-06		x								Pilot not on oxygen above 10,000 ft
172	Cessna Citation 560XL, G-OROO	29-Jun-08			x							Correction discard
116	Boeing 757-204,G-BYAO	22-Oct-06		x								Smoke in cockpit, failed LP turb bearing seal, oil migrates ionto compressor flow
143	Boeing 777-236, G-ZZZC	10-Jan-06	x								x	During pushback, left wing walker distracted, struck another aircraft
84	Boeing 737-33V, G-EZYN	22-Mar-05		x								Battery bus relay failed
152	British Aerospace HS 748 Series 2A, G-BGMN	28-Jan-05	x								x	Escape hatch lever safety cover not installed, argo loaders inadvertantly unlocked overwing escape hatch during cargo loading operations, hatch departed AC in flight
233	Lockheed L188C, G-FIZU	19-Mar-07		x								Synchrophaser failed in flight, erratic engine operation
59	BAe 146-100, G-MABR	26-Jun-03		x								Turbulence, pax and cabin crew injured

87	Boeing 737-377, G-CELA	7-Jul-06		x								AP disengaged, CB tripped, aircraft failed to capture GS, pilot had difficulty controllong pitch
175	Cessna T310R, G-OGTX	13-Mar-04		x								Training flight crashed, ultimate caused unknown but suspected operational rather than technical
157	Britten-Norman BN2A Mk III-2 Trislander, G-BEDP	14-Apr-07	x								x	Marshallers signalled clear, aircraft struck another aircraft
213	Embraer EMB-145EP, G-RJXD	25-Jun-04	x								x	Baggage truck struck aircraft
252	S4/2008 - Airbus A340-313, G-VAIR	27-Apr-08		x								Poor visability, one MLG off paved surface on landing in Kenya
122	Boeing 757-28A, G-OOOD	17-Feb-03		x								Aircraft could not maintain cabin altitude, engine warning light
11	Airbus A319-111, G-EZEG	30-Dec-05		x								Crew reported smoke in cockpit, no evidence of same on ground
49	Avro 146-RJ100, G-CFAC	18-Mar-05			x							Bulletin on freezing deice fluid residue-discard
226	Jetstream 31, G-EEST	17-Sep-03		x								High speed hard landing cracked spar
41	Airbus A340-311, G-VSKY	30-Jan-03		x								Ice on taxiway aircraft slid off paved surface
77	Beech 200 Super Kingair, G-ROWN	5-Aug-03		x								Gear w/n retract, return to field, gear collapsed on landing, several theories
179	DH89A Dragon Rapide, G-AIYR	9-Jul-05		x								Flame from exhaust set fabric wing cover on fire
168	Cessna 550 Citation, G-FCDB	25-Nov-04			x							Report withdrawn
241	Raytheon 390 Premier I, G-FRYL	7-Aug-08		x								Pitot tube blocked by ice, (IAS comparator worning, loss of air data, water drained from pitot static plumbing, pitot heat checked good

212	Embraer EMB-145EP, G-RJXA	16-Jan-03	x								x	After pushback ground crew cleared pilot to start second engine by cross flow from first (air cart died) while tug was pulling aircraft forward to taxiway centerline, aircraft accelerated, broke towbar, struck tug
205	Embraer 135ER, G-RJXK	16-Jan-03	x								x	Baggage load team member did not chock baggage trailer (had defective brake), trailer rolled and struck aircraft
135	Boeing 777-236, G-VIIC	28-Mar-04		x								Lavoratory supplies in contact with light ballast ignited, fire
151	Bombardier DHC-8-402, G-JECI	9-Jan-07		x								Pilot lost on arfield, one MLG stuck in soft ground during u-turn
3	ATR42-300, G-TAWE	20-Jan-06			x							Bad address
219	Fokker F27 Mark 500, G-CEXG	7-May-04		x								FO observed mechs cahrging pneumatic system, suspected system leaks and pulled isolating valve pin to store charge in air bottle (inadvertantly disabled part of system) during taxi, pilot lost control and departed taxiway
203	Dornier 328-100, G-BYML	15-Nov-05		x								Smoke in cabin, engine oil migrated to ECS pac
10	Airbus A319-111 Airbus, G-EZDM	15-Dec-08		x								Hyd sys lo lvl light, followed by second hyd sys overht light (connectd via PTU), dmaged failed hoses
102	Boeing 747-436, G-BNLE	22-Nov-06		x								Faulty stair truck, platform came down on wing root after being positioned,

												electrical componenet in jack system failed
160	Cessna 208B Caravan, G-BZAH	4-Nov-04		x								Nose strut attachment failed during aircraft ground movement
231	Jetstream 4102, G-MAJV	9-Apr-08		x								Aircrew elected to forego deice and antiice procedures to avoid delay, ice jammed elevator
225	Interim Report - Boeing 777-236ER, G-YMMM	17-Jan-08		x								Ice restricted fuel to both engines
170	Cessna 560XL, G-WCIN	8-Jul-05	x			x	x					SPR cover not reinstalled after refuel, cover struck engine fan, engine vibration, mission continued with reduced engine power
257	SD3-60 Variant 100, G-GPBV	19-Aug-08		x								Water leaked past window seals shorted flap lever, burning smell, crew were not familiar with type of smoke mask on aircraft
165	Cessna 550 Citation Bravo, G-IKOS	5-Feb-08		x								Windshear on landing
220	Grob G109B, G-BZLY	27-Sep-03		x								Aircraft touchdown on nose, pilot corrected , lost control, nose over
31	Airbus A321-211, G-DHJH	18-Jul-08		x								"Severe hard" landing, pilot elected not to report, subsequent inspection after later flights discovered cracked structure
51	Avro 146-RJ100, G-CFAE	11-Jan-06		x								Pilots did not follow start procedure for second engine with APU disabled, did not increase rpm on first engine, operating engine loaded down by second engine, overfuelled started tail pipe fire

82	Boeing 737-33A, G-TOYE	15-Jan-06	x								x	After pushback, ground crew requested parking brake be applied, disconnected towbar, aircraft rolled and struck tug, AC brake applied on second request but too late
112	Boeing 747-443, G-VROM	26-Jul-05		x								Turbulence during cruise phase
15	Airbus A319-131, G-DBCI	18-Apr-07		x								Rudder pedal input for unknown reason caused rapid 18 degree turn just before liftoff, aircraft became airborne before departing edge of runway and maneuvered back to runway centerline, subsequent flight uneventful
64	BAe 146-200, G-MANS	1-Aug-03	x			x		x				APU oil leak fumes in cockpit, missing bearing assembly o-ring did not contribute to incident, but mechanic error on overhaul
156	Britten-Norman BN2A Mk III-1 Trislander, G-LCOC	7-Jun-06	x								x	Baggage door not properly secure by ground staff
272	Summary AAR 2/2007 Boeing 777-236, G-YMME	10-Jun-04	x			x			x			Rear spar door pf center wing tank not reinstalled after maintenance, fuel leak (massive)
60	BAe 146-200, G-GNTZ	6-Oct-04		x								Pilot taxied into airbridge while attempting to park using PAPA and AGNIS
36	Airbus A321-231, G-MIDJ	26-May-03		x								Turbulence, hail damage
129	Boeing 767-304, G-OBYH	21-Oct-04		x								During u-turn, aircraft tire and runway laight damage
94	Boeing 737-73V, G-EZJN	2-Sep-03	x								x	Ground crew left tug in parking position while AGNIS activated and guiding aircraft onto

												stand, aircraft struck tug short of normal AGNIS stop position
78	Beech B200 King Air, G-PCOP	28-Mar-06		x								Pilot inadvertantly shutoff both generators, battery failed 13 minutes later, at some point over-g occurred, pilot did not report over-g, aircraft made subsequent flight with damaged ing panels
139	Boeing 777-236, G-VIIP	14-May-06		x								Turbulence
124	Boeing 757-2T7, G-MONE	17-Mar-06		x								Crew called missed approach but did not follow proper missed approach procedures
105	Boeing 747-436, G-BNLZ	26-Feb-03	x								x	While cargo door being closed, door struck freight vehicle hand rail
46	Airbus A340-642, G-VSHY	23-Apr-05	x								x	Incorrect load plan, aircraft 3200 lbs over original load plan and CG OOT, error discovered after aircraft departure, CG corrected in flight
126	Boeing 757-3CQ, G-JMAA	23-Nov-04		x								Roll input during autoland flare, caused by ILS interference from anther aircraft
44	Airbus A340-642, G-VGOA	30-Dec-05		x								Oil buildup from blocked drain hole, oil ingessted by APU, fumes in cockpit
92	Boeing 737-528, G-GFFE	3-Sep-05		x								APU contained turbine failure, casting defects not detectable through approved inspection procedure
9	Airbus A300B4-605R, G-MONR	27-Jan-03		x								Clear air turbulence
69	BAe 146-300, G-JEBC	6-Sep-07		x								Fumes in cabin, possibly degraded toilet cleaning materials crew

												stand, aircraft struck tug short of normal AGNIS stop position
78	Beech B200 King Air, G-PCOP	28-Mar-06		x								Pilot inadvertantly shutoff both generators, battery failed 13 minutes later, at some point over-g occurred, pilot did not report over-g, aircraft made subsequent flight with damaged ing panels
139	Boeing 777-236, G-VIIP	14-May-06		x								Turbulence
124	Boeing 757-2T7, G-MONE	17-Mar-06		x								Crew called missed approach but did not follow proper missed approach procedures
105	Boeing 747-436, G-BNLZ	26-Feb-03	x								x	While cargo door being closed, door struck freight vehicle hand rail
46	Airbus A340-642, G-VSHY	23-Apr-05	x								x	Incorrect load plan, aircraft 3200 lbs over original load plan and CG OOT, error discovered after aircraft departure, CG corrected in flight
126	Boeing 757-3CQ, G-JMAA	23-Nov-04		x								Roll input during autoland flare, caused by ILS interference from anther aircraft
44	Airbus A340-642, G-VGOA	30-Dec-05		x								Oil buildup from blocked drain hole, oil ingessted by APU, fumes in cockpit
92	Boeing 737-528, G-GFFE	3-Sep-05		x								APU contained turbine failure, casting defects not detectable through approved inspection procedure
9	Airbus A300B4-605R, G-MONR	27-Jan-03		x								Clear air turbulence
69	BAe 146-300, G-JEBC	6-Sep-07		x								Fumes in cabin, possibly degraded toilet cleaning materials crew

55	BAC Concorde Type 1 Variant 102, G-BOAC	4-Oct-03		x								Smoke in cockpit, cause not determined before Concorde withdrawn from service
47	Avro 146-RJ100, G-CFAA	20-Sep-06	x				x	x	x			Smoke in cockpit repeat, engine oil leak, oil migrated to AC pac, engine change, next flight smoke since maintenance did not successfully remove oil from pac
154	British Aerospace Jetstream 3102, G-CCPW	7-Mar-06		x								Pilot taxied off runway onto unpaved surface, water droplets may have distorted vision
186	DHC-8-311 Dash 8, G-JEDE	29-Nov-04		x								Low speed, high sink rate, tailstrike
32	Airbus A321-211, G-SMTJ and Boeing 737-2E7, EI-CJI	29-Feb-04		x								Runway incursion by aircraft while another aircraft on takeoff roll
227	Jetstream 3202, G-BYRA	10-Jan-05		x								Manufacturer defect in gearbox, drive gear rim separation
188	DHC-8-311, G-BRYU	21-Dec-04		x								Elevator tab springs frozen, possibly by deice fluid residue trapped in aerodynamically quiet areas
183	DHC-8-311 , G-BRYU	20-Jun-05		x								Hyd leak fell on hot components of radar, smoke issued from nose if aircraft
131	Boeing 767-31K, G-DAJC	21-Oct-06		x								Smoke in cockpit, new engine installed pretested
22	Airbus A320-231, G-MEDA Ethiopian CAA	31-Mar-03		x								Incorrect VOR information from Addis Abebe VOR
20	Airbus A320, G-DHJZ	5-Jul-07		x								Late flare, high rate of descent, hard landing
185	DHC-8-311 Dash 8, G-BRYW	28-Oct-03		x								Turbulence

251	S3/2008 - Boeing 777-236 ER, G-YMMM	17-Jan-08			x							Ice in fuel system, covered in another report in this sample-discard
247	S1/2009 - Embraer 190-200, G-FBEH	15-Jan-08		x								Suspected smoke from galley sink, intercom failed, cabin crew could not contact or gain access to cockpit (flight deck access disable on emergency power)
184	DHC-8-311 Dash 8, G-BRYW	7-Oct-05	x								x	After disconnect GPU rolled forward, under power and struck aircraft, GPU worn gear selector may have allowed vehicle to move, but vehicle parked facing aircraft against company policy

Appendix D:

U.S. 1995-2000 Sample

	Report Information		Maintenance			Error Category						
	Sample	Records	0 225	0 78		0 23	0 06	0 29	0 19	0 03	0 32	
	138	963	31	107	14	7	2	9	6	1	10	
ID	Date	Aircraft	Yes	No	Discards	Installation	Servicing	Repair	Inspection	Foreign Object	Equipment	Remarks
605	2/28/1999	Piper PA-23-250		x								Hard landing, nose touchdown, structural damage
31	9/15/2000	Boeing 737-49R	x								x	Tow team struck another aircraft, wigwalkers signalled stop, tug drive did not see
103	11/2/1999	Boeing 737-400		x								Plows on runway FSS did not provide advisory of equipment on runway
454	3/16/1995	BOEING 727-200		x								Clear air turbulence
342	8/14/1996	Boeing 727-232		x								Failure of the low pressure turbine assembly for undetermined reason
659	6/9/1998	Cessna 207A	x			x		x	x			Failure of maintenance personnel to properly install a wire bundle clamp, chafing, arcing, and subsequent leaking of a fuel line, which resulted in an in-flight fire A factor associated with the accident was company maintenance personnel's

												failure to discover a missing clamp during a 100 hour inspection
578	8/6/1999	Cessna T210M		x								The pilot's failure to maintain sufficient airspeed during final approach to landing, resulting in an inadvertent stall
670	4/23/1998	Beech 58			x							Bad address
313	1/31/1997	Boeing 757-232			x							Bad address
392	1/17/1996	Airbus Industrie A-300B4-605R		x								Turbulence
741	7/5/1997	de Havilland DHC-2		x								Loss of engine power due to the fatigue failure of the no 1 exhaust push rod Factors contributing to the accident were insufficient information on pushrod inspection and overhaul from the manufacturer
726	8/23/1997	Helio H-295		x								Failure of the pilot to maintain directional control of the airplane, which resulted in a swerve and collision with a tree as the pilot continued the takeoff, subsequently jamming the stabilator and causing the plane to crash in water
441	5/19/1995	BOEING 727-227		x								An elderly passenger losing his balance as the aircraft operated in smooth air

687	2/6/1998	Cessna 207	x						x			Fatigue failure, and partial separation of the number 6 engine cylinder head assembly, the operator's inadequate progressive inspection performed by company maintenance personnel,
922	6/2/1995	PIPER PA-32-260		x								Missing aircraft
686	2/23/1998	Beech 100		x								Ice formation around the elevator control cables due to plugged limbers and a water drain hole
315	1/22/1997	de Havilland DHC-8-102		x								Fractured fusion weld in the piston of the roll spoiler servoactuator, which allowed the plug at the base of the piston to separate and jam the piston A factor relating to the incident was the inadequate design of the airplane's roll spoiler servoactuator piston
450	4/7/1995	BOEING 737-222		x								Deterioration of lubricating grease in the wheel bearing, which led to the total bearing failure and subsequent loss of the wheel Factors were the insufficiently defined procedures for repacking the bearing, along with an insufficient method of retaining lubricant within

												the bearing
919	6/24/1995	CESSNA 172	x				x					The pilot's failure to maintain directional control A factor relating to the accident was the diminished nosewheel steering capability due to an overinflated nosewheel strut
685	2/23/1998	Piper PA-23-250		x								An improper preflight inspection of the airplane by the pilot and the inadvertant stall/mush which was encountered A factor associated with this accident was the pilot's decision to continue to use the emergency hydraulic hand pump rather than the co2 bottle to extend the landing gear which resulted in the landing gear not fully extending
890	11/5/1995	CESSNA 206		x								The pilot's inadequate visual lookout A factor associated with the accident is reduced visibility due to sun glare

813	9/1/1996	Piper PA-32		x								Pilot's inadvertent flight into instrument meteorological conditions
765	3/6/1997	Beech E-18S		x								Pilot's disregard of the preflight weather briefing for severe weather along his route of flight, and his departure into the known and forecasted severe weather
538	2/5/2000	Cessna U206G			x							Bad address
291	4/16/1997	Boeing 737-500		x								A laser light source of undetermined origin, directed by unknown person(s) toward the cockpit window of the aircraft, while the aircraft was on an approach to land
743	7/3/1997	Piper PA-32		x								Jamming/failure of the left magneto impulse coupling, which stopped rotation of the magneto gear, and resulted in subsequent shearing of the accessory intermediate idler gear Factors relating to the accident were the lack of suitable terrain for a forced landing, which necessitated ditching of the aircraft, the passenger's lack of awareness concerning access to life vests, due to the pilot's inadequate briefing and the seat covers being installed over pouches that held the life

												vests, insufficient company standards/procedures regarding access to life vests
449	4/11/1995	BOEING 757-223		x								Pilot-in-command's failure to set the parking brake
958	1/18/1995	CESSNA 208B		x								The pilot's failure to remove ice from the airframe prior to takeoff Factors were freezing rain the night before and the pilots' incomplete preflight inspection
139	5/25/1999	Boeing 737		x								Turbulence
219	3/9/1998	Canadair CL600-2B19	x								x	Operation of a ground vehicle at night with an inoperative windshield wiper and an obscured windscreen against company regulations which resulted in a collision with a parked aircraft
102	11/7/1999	McDonnell Douglas DC-10-30F		x								Near midair collission
185	9/17/1998	Aerospatiale ATR-42-300		x								Turbulence
541	1/27/2000	Cessna 310R		x								Failure of the pilot-in-command to follow the prescribed instrument approach missed approach procedure

447	4/27/1995	Airbus Industrie A320-211		x								PIO failure to heed flight manual notes
700	11/11/1997	Piper PA-31-T3		x								Nit moose on takeoff
770	2/20/1997	Cessna T210N		x								Lost radar contact, no wreckage
43	7/28/2000	Boeing 727-200		x								Pilot's inadequate evaluation of weather information, and his delay in taking remedial action that resulted in the in-flight encounter with severe weather
851	4/17/1996	Cessna 206G		x								Pilot's continued VFR flight into instrument meteorological conditions
187	9/2/1998	Douglas DC-9-30	x								x	Airplane struck fuel truck, failure of the fuel truck driver to follow airport operating procedures, and yield the right-of-way to the airplane
603	3/5/1999	Swearingen SA226TC		x								Ground collision w/another aircraft
94	1/11/2000	Boeing 757-2G7			x							Bad address
545	12/23/1999	Cessna 185		x								Pilot's selection of an unsuitable takeoff area during the incoming tide
886	12/10/1995	PIPER PA-32-300		x								Pilot's inadequate compensation for wind conditions
147	3/31/1999	Fokker F 28 MK 4000	x						x			Maintenance failed to detect chafed and leaking hydraulic line

425	8/3/1995	Dornier DO 328-100		x								Aircraft veers left on landing, condition levers to min gives maximum steering effect
775	1/27/1997	Cessna U206D	x			x						Inadequate torque of the cylinder base nuts and through bolt nuts by company maintenance personnel which allowed movement of the crankcase halves As a result the No 2 main bearing failed which allowed excessive movement of the crankshaft resulting in fatigue failure of the crankshaft
879	1/4/1996	BEECH B100		x								Failure of airport personnel to properly remove snow from the runway or issue an appropriate notam concerning the runway condition Factors relating to the accident were the low light condition at dawn, and the snowbank or berm that was left on the runway
368	5/16/1996	McDonnell Douglas MD-11-F		x								Wake turbulence on final
943	3/10/1995	CESSNA 207A		x								Pilot's continued visual flight rules (vfr) flight into instrument meteorological conditions
870	2/7/1996	Beech 1900D		x								Pilot misjudged the flare during landing

228	1/20/1998	Beech 1900D		x								Inadequate snow removal from the runway by airport personnel which left a snow bank extending onto the runway
779	1/13/1997	Piper PA-32-260		x								Pilot's failure to maintain proper runway alignment during the takeoff roll A factor associated with the accident was the snowbank which the airplane contacted
810	9/3/1996	Cessna 206		x								Pilot's inadequate compensation for the wind conditions
740	7/7/1997	Cessna U206G		x								Pilot's misjudgment of the proper touchdown point A factor associated with the accident was a tailwind
525	3/31/2000	Beech 58		x								Pilot's inadvertent VFR flight into IMC
668	5/12/1998	Dassault DA-20		x								Pilot-in-command's inability to rotate during takeoff due to restricted movement of the elevator controls for undetermined reasons
664	5/21/1998	Cessna 207			x							Bad address
445	5/1/1995	MCDONNELL DOUGLAS DC10-10	x			x						Failure of the safety wire and/or safety wire lug arm on one of the stage one to two disk flange bolts due to an inadequate safetying method

431	7/4/1995	BOEING 727-257	x					x				Gear trunnion blended below minimum, A shear failure of the right main landing gear outer cylinder trunnion due to fatigue and stress corrosion, and the operator's inadequate and improper overhaul procedures
108	10/5/1999	McDonnell Douglas MD-11F		x								Divergent, longitudinal oscillation of undetermined origin on the center landing gear, which caused a failure of the center landing gear lower drag brace during landing roll
510	7/8/2000	Cessna 402C		x								Airplanes entry into an uncontrolled descent for undetermined reasons from which it crashed into the ocean
647	8/11/1998	Piper PA-31-350		x								Forgot to put gear down, pilot's failure to follow the pre-landing checklist A factor associated with the accident was the pilot's diverted attention
422	8/5/1995	BOEING 727-264	x								x	AC collided with tug, THE FAILURE OF THE GROUND CREW TO FOLLOW PROCEDURES/ DIRECTIVES REQUIRING THAT THE AIRPLANE BRAKES BE SET BEFORE DISCONNECTING THE TOW BAR FROM THE AIRPLANE
921	6/22/1995	PIPER PA-31-350			x							Bad address

149	3/17/1999	Boeing 737-300		x								Flight attendant's failure to follow cabin door opening procedures
346	7/13/1996	McDonnell Douglas MD-11		x								Insufficient information from the manufacturer in the airplane flight manual and flightcrew operating manual regarding the hazards of applying force to the control wheel or column while the autopilot is engaged
285	5/4/1997	Boeing 737-201		x								Flight attendant's failure to assure that the jetway was placed in the proper position prior to opening the forward cabin entry door
496	8/28/2000	Cessna T210N	x					x				Fatigue failure of the crankshaft due to improper overhaul procedures
293	4/9/1997	McDonnell Douglas DC10-30F		x								Stall buffet or a high speed buffet event which occurred at an undetermined time
395	12/30/1995	ATR ATR 42-300			x							Bad address
5	12/27/2000	Embraer EMB-135LR		x								The jammed horizontal stabilizer trim that occurred during the airplane's initial climb after takeoff Factors relating to the incident were the inadequate capability of the horizontal stabilizer trim actuator to move the stabilizer during all flight phases, and the inadequate design of the system by the manufacturer

311	2/13/1997	Boeing 727-232	x			x						Failure of ground service personnel to properly close the aft cargo door before the airplane departed
882	12/20/1995	CESSNA T210N	x					x				Failure of the turbocharger, caused by a unapproved rebuild of the turbocharger which contained automotive parts
86	2/15/2000	Beech 1900D		x								Failure of the flightcrew to maintain directional control due to unsafe/hazardous conditions on the runway that was not relayed to them
559	10/25/1999	Learjet 35		x								Incapacitation of the flight crewmembers as a result of their failure to receive supplemental oxygen following a loss of cabin pressurization, for undetermined reasons
738	7/8/1997	Piper PA-18-160		x								Pilot's failure to maintain sufficient altitude to clear terrain Factors were exceeding the airplane's maximum allowable gross weight, and downdrafts and turbulence associated with wind flowing across a mountain ridge

391	2/1/1996	DOUGLAS DC-9-32	x						x			Failure of the right main landing gear shock strut cylinder due to preexisting fractures Contributing to the accident was the failure of the operator to inspect the shock strut cylinder for fractures following a previous failure of the torque links
115	9/12/1999	Boeing 737-322	x								x	Lavatory service driver's failure to follow established company procedures and directives A factor in the accident was the airline's use of a one person pushback procedure
912	7/13/1995	de Havilland DHC-3			x							Bad address
134	6/11/1999	Boeing 777-222		x								Pilot-in-command's inadequate evaluation of the weather conditions

111	9/20/1999	Boeing 757-2S7	x					x	x			Systemic failure of the airline's maintenance department to identify and correct the long standing history of intermittent faults, nuisance warnings, and erratic behavior in this airplane's GPWS system Also causal is the airline's failure to perform the service bulletins and service letter upgrades to the system, which would have eliminated or greatly reduced the likelihood of this particular nuisance warning, a condition that was identified and corrected by the manufacturers 11 years prior to the accident, and was the subject of one or more of the SB/SL upgrades
787	12/12/1996	de Havilland DHC-2		x								Pilot's inadequate compensation for wind conditions
783	1/5/1997	Fairchild SA227-AC		x								Failure of the pilot(s) to use 'override' ignition as prescribed by checklist procedures during an encounter with icing conditions, which subsequently led to ice ingestion and dual engine flame-outs

892	10/26/1995	Beech 65-B80		x								Pilot's impairment of judgment and performance due to alcohol which resulted in his improper decision to shutdown an engine, and his failure to maintain adequate airspeed for single-engine flight
309	2/20/1997	McDonnell Douglas DC-9-15			x							Bad address
739	7/8/1997	Aero Commander 500-B	x					x				Factors were the partial loss of engine power due to the cracks in the #1 and #4 cylinders as the result of an unapproved modification of their intake ports
504	8/9/2000	Piper PA-31 NAVAJO		x								Failure of the pilots of the two airplanes to see and avoid each other and maintain proper airspace separation during visual flight rules flight
646	8/13/1998	Piper PA-34-200T		x								Pilot's inadequate landing flare, causing components of the nose wheel landing gear to fracture
167	12/26/1998	McDonnell Douglas MD-88		x								Passenger sustained a hairline fracture during an emergency evacuation of the airplane

405	11/7/1995	BOEING 737-200		x								The passenger failure to follow the instructions to be seated and utilize a seatbelt Contributing to the accident was the in flight encounter with turbulence
697	12/8/1997	Cessna 402A			x							Bad address
718	9/8/1997	Cessna 402C		x								Failure of the pilot of the Cessna 402C, N2649Z, to maintain adequate clearance while taxiing alongside the stationary Cessna 208B, N1123R
390	2/4/1996	MCDONNELL DOUGLAS MD-88		x								Failure of the pilot to maintain sufficient airspeed to properly flare the airplane during the landing
78	3/10/2000	Aerospatiale ATR-72-212		x								Flight attendant's failure to seat and belt herself during an inflight encounter with turbulence
493	9/14/2000	Cessna 208B		x								Pilot's improper securing of the cargo that led up to the cargo shift during takeoff roll A factor was the cargo restraint failure
590	4/27/1999	Cessna 402C	x						x			Fatigue failure of the right wing spar as a result of inadequate quality control during manufacture of the spar A factor was the inadequate inspection of the right wing by maintenance personnel, which failed to detect the crack

941	3/17/1995	BEECH 1900C		x								An axial shift of the outer bearing roller for an undetermined reason, resulting in erosion and failure of the flap track hinge bracket/bearing assembly Factors relating to the incident were the roller bearing and associated bracket assembly within the interior of the flap structure could not be adequately inspected without disassembly, and lack of inspection criteria in the manufacturer's maintenance manual concerning flap roller/hinge bracket assemblies
269	7/4/1997	McDonnell Douglas DC-8-61			x							Bad address
434	6/25/1995	Airbus Industrie A-300-B4-103			x							Bad address
76	3/12/2000	Boeing - Canada (de Havilland) DHC-8-102			x							Bad address
710	10/20/1997	Piper PA-32RT-300		x								Improper engine operation by undetermined person(s) that initiated gauling on the connecting rod, and led to its subsequent failure

791	12/4/1996	Cessna 172M		x								Pilot's improper planning/decision, and resultant failure to obtain/maintain sufficient airspeed during takeoff A factor related the accident was taking off with a tailwind
699	11/13/1997	Beech 65-A90		x								Failure of the pilot to maintain the minimum required airspeed while operating in icing conditions which resulted in ice accumulations and an inadvertent stall while on approach
105	10/15/1999	Airbus Industrie A-320-231	x								x	Causal was the failure of the tug driver and the wing walkers to maintain adequate communications during the pushback
12	11/29/2000	McDonnell Douglas DC-9-82	x			x		x				Operator's inadequate maintenance procedure to disconnect the Omega navigational system, which resulted in coaxial cables being cut and not properly protected
402	11/25/1995	Boeing 737-522		x								Moderate high level windshear and turbulence
778	1/17/1997	Cessna 207A		x								Pilot's decision to continue VFR flight into instrument meteorological conditions
549	12/8/1999	Cessna T210L		x								Pilot's failure to maintain aircraft control for reasons undetermined

956	1/26/1995	BEECH E18S		x								The pilot's failure to follow the ifr procedure by not maintaining the proper altitude prior to the initial appraoch fix
594	4/11/1999	Piper PA-31-350		x								Pilot's inadequate in-flight planning/decision, and his failure to attain the proper touchdown point on the runway
217	3/11/1998	Fokker F-100	x								x	Fuel truck struck aircraft, driver's failure to maintain clearance from the parked airplane Related factors were night conditions and the driver's diverted attention
145	4/12/1999	Saab-Scania AB (Saab) 340B	x								x	Belt-loader driver's loss of control of the vehicle, and his failure to follow published procedures for approaching the airplane with the belt-loader
585	6/25/1999	Beech C90		x								Poor in-flight weather evaluation by the pilot-in-command and his operation of the airplane at an indicated airspeed greater than the design maneuvering speed (Va) in a thunderstorm contrary to the pilot's operating handbook resulting in an in-flight breakup
168	12/21/1998	Boeing 727-233		x								Snow removal not done by other person

298	3/27/1997	Boeing 767-232		x								Manufacturer's improper installation of the flap, which resulted in fatigue cracking of the flap attach bolts and separation of the flap
872	1/27/1996	Aerostar 601		x								Loss of power in the right engine for undetermined reason(s), and the accumulation of structural ice on the airplane, which resulted in an increased rate of descent and a subsequent forced landing before the pilot could reach an alternate airport
68	3/28/2000	Airbus Industrie A-300-600		x								Oil leak from the aircraft's APU that subsequently contaminated the aircraft's environmental system
868	2/16/1996	Cessna 172P		x								Pilot's selection of the wrong runway for landing, by not observing a procedure to land uphill during calm wind conditions, and his subsequent failure to retract the flaps during landing roll
929	4/16/1995	FAIRCHILD SA-227	x			x						Improper installation of the rudder trim actuator rod by company maintenance personnel which resulted in binding and fracture of the rod
253	9/6/1997	British Aerospace BAE-ATP		x								Sudden/unexpected encounter with clear air turbulence

875	1/18/1996	Cessna T210M		x								Failure of the throttle cable A factor relating to the accident was the lack of suitable terrain for a forced landing
746	6/4/1997	Cessna 177B		x								Loss of engine power for undetermined reasons
902	8/26/1995	PIPER PA-28-181		x								Failure and separation of the propeller blade due to foreign object damage and fatigue
725	8/24/1997	Piper PA-32-300		x								Pilot's improper selection of a fuel tank that did not contain fuel, *which resulted in* subsequent fuel starvation and loss of engine power
621	12/4/1998	Stinson 10A	x					x				Failure of company maintenance personnel to replace an inoperative fuel gauge, and subsequent fuel exhaustion
880	12/28/1995	Fairchild SA227-AC	x			x						Inadequate maintenance installation and inspection of the elevator flight control system which led to restricted flight control elevator movement due to a loose bolt
2	12/29/2000	Jetstream 4101			x							Bad address
831	7/6/1996	Beech 18		x								Malfunction of the propeller control unit on the right engine
716	9/26/1997	Cessna 207A		x								Improper in-flight planning/decision by the pilot, and his failure to maintain sufficient altitude over mountainous terrain

202	5/24/1998	Boeing 757-2B7		x								Severe turbulence encountered as a result of the flightcrew's inadvertent flight into a rapidly developing thunderstorm
720	9/6/1997	Cessna 207A		x								Pilot's inadequate evaluation of the weather conditions
180	10/21/1998	Boeing MD-11	x							x		Jammed spoiler control pulley system caused by a shop rag left in an area of recent maintenance Neither the maintenance organization nor the mechanic responsible could be determined
946	3/2/1995	CESSNA 208B		x								Pilot's continued flight into adverse weather conditions Factors were the icing conditions prevailing at the destination airport, and the pilot's inability to maintain visual lookout due to windshield icing
894	10/10/1995	CESSNA 172RG		x								Pilot's failure to maintain adequate terrain clearance A factor was the pilot diverting attention while looking for game
245	10/4/1997	Boeing 737-200	x					x				Improper repair to a crack in a brake flange hole on the left main landing gear outboard axle, and subsequent fatigue failure of the axle
120	8/13/1999	Aerospatiale ATR-42-300	x								x	Failure of the ramp service clerk to maintain clearance with the operating propeller

325	12/15/1996	de Havilland DHC-8	x				x					Inadequate servicing by company maintenance personnel Factors were the emergency landing gear extension systems dirty and binding condition, a worn emergency landing gear extension cable
382	2/20/1996	British Aerospace AVRO 146-RJ70A		x								Copilot's failure to compensate for wind conditions, resulting in excessive airspeed, and his failure to attain the proper runway touch down point
877	1/12/1996	Cessna T210N		x								Pilot's misjudgment of the fuel supply, which resulted in a loss of engine power due to fuel exhaustion during final approach to the destination airport
287	4/28/1997	Boeing 737-200		x								Failure of the flight crew to alert the cabin crew to the possibility of turbulence
526	3/27/2000	Piper PA-32R		x								Pilot's misjudgment of distance/altitude, and subsequent undershoot during landing
582	7/3/1999	Piper PA-31-350		x								Loss of engine power due to fuel exhaustion because the pilot failed to refuel the airplane
933	4/2/1995	BEECH G18S		x								Engine compartment fire due to undetermined reasons
593	4/14/1999	Cessna 207A		x								Pilot's continued VFR flight into instrument meteorological conditions

942	3/14/1995	BEECH 58		x								Failure of the landing gear bushing for the actuator worm gear which resulted in both the normal and emergency gear extension systems being inoperative
220	3/6/1998	Douglas DC-10-30F	x								x	Ground personnel (an equipment loader) failed to follow established written procedures (ramp safety policy), resulting in a pressurized entry door being opened before it was fully depressurized, subsequently injuring the equipment loader
446	4/28/1995	Airbus Industrie A320-211		x								Inadequate design of the fly-by-wire flight control system which allowed false signals from the sidestick transducer units to generate uncommanded rolls
261	7/31/1997	McDonnell Douglas MD-11		x								Overcontrol of the airplane during the landing and his failure to execute a go-around from a destabilized flare
35	8/22/2000	Boeing 777-223		x								Unexpected turbulence encountered by the airplane

112	9/17/1999	McDonnell Douglas MD-88		x								Manufacturer defect deteriorated wire insulation and shorting at a short radius bend to the electrical wiring in the right side alternate static port heater, which resulted in electrical arcing and a fire sustained by overlaying thermal acoustic insulation
337	9/20/1996	Saab-Scania AB (Saab) SF-340B		x								Passenger fell for undetermined reasons, while disembarking from the airplane
318	1/7/1997	Airbus Industrie A-300B4-605R		x								Unforecast clear air turbulence

Appendix E:

U.S. 2003-2008 Sample

	Report Information		Maintenance			Error Category						
	Sample	Records	0 167	0 83		0 17	0 09	0 2	0 3	0	0 39	
	138	646	23	115	5	4	2	5	7	0	9	
ID	Date	Aircraft	Yes	No	Discards	Installation	Servicing	Repair	Inspection	Foreign Object	Equipment	Remarks
381	4/12/2008	EMBRAER EMB-110P1		x								Pilot lost control during landing
182	7/11/2005	Boeing 767-232		x								Clear air turbulence
277	10/12/2003	McDonnell Douglas DC-10-10		x								Manufacturer defect, caused flap disagreement
560	9/18/2004	Cessna 401		x								Fuel starvation, AC crashed on go-around
357	9/12/2008	CESSNA 207		x								The pilot's inadequate evaluation of weather and runway conditions, and his improper decision to depart downwind, on a wet gravel runway, resulting in an in-flight collision with terrain after takeoff Factors contributing to the accident were a tailwind, and an uphill grade of the wet, gravel-covered runway
440	1/10/2007	Learjet 35A		x								Pilot lost control during intentional aileron roll maneuver

421	6/13/2007	Piper PA-31-350		x								Pilot failed to refuel airplane, fuel starvation
246	6/11/2004	Embraer EMB-135LR		x								On landing NW had uncommanded risght steer, contamination blocked port in steering manifold
93	2/16/2007	Airbus Industrie A319-111		x								FOD impact cracked windscreen
173	8/29/2005	Airbus Industrie A330-223		x								Airbus struck Bambardier while taxiing
456	7/31/2006	de Havilland DHC-3		x								Pilot failed to maintain alt, float plane, struck water
505	8/21/2005	Cessna U206E		x								Pilot misjudged altitude and distance on approach, landed short
618	7/13/2003	Cessna 402C	x					x	x			Undocumented inadequate maintenance resulted in engine failure in flight
553	10/11/2004	Cessna 207		x								Bird strike on final
317	4/21/2003	Boeing 757-222		x								Turbulence
625	6/9/2003	Cessna 185		x								Excessive taxi speed, skiplane MLG sank into snow during turn
66	7/11/2007	Airbus A-320		x								Runway incursion by aircraft
2	12/28/2008	BOEING 737-832	x								x	Ramp controller cleared two pushbacks same time, tug operator and wing walker failed to maintain adequate clearance, aircraft collided tails
508	8/4/2005	de Havilland Beaver DHC-2		x								Mid air collision, ATC and pilot failed to maintain separation

8	12/15/2008	BOMBARDIER CL-600-2C10			x							Bad address
611	9/5/2003	Cessna 206		x								Pilot failed to maintain airspeed during initial climb, AC settled on muddy runway, ground loop, MLG failed
184	6/28/2005	Canadair CL-600-2B19		x								NLG collapsed, improper assembly of valve by manufacturer/supplier
154	12/15/2005	Boeing B737-924		x								Aircraft collision on ground, pilot inadvertantly entered uncontrolled non-movement area
128	6/8/2006	Boeing 737-300		x								FOD left on taxiway by taxiway maintenance personnel struck AC
326	3/26/2003	Boeing 717-200		x								Smoke in cockpit instrument and cockpit lights inop, DC bus fail due to PCU failure
292	8/13/2003	Bombardier CL600-2B19		x								Utility bus relay fail, fire, smoke in cockpit
36	2/22/2008	Boeing 737-700		x								Turbulence on approach
78	5/26/2007	Embraer 120		x								Near miss on take off, intersecting runways
462	6/2/2006	Gates Learjet 35A		x								CFIT, pilot did not have decision height criteria, continued to descend into water hit light poles
100	12/26/2006	Boeing 737-7H4		x								Taxiing aircraft struck stationary aircraft on ramp
80	5/2/2007	MCDONNELL DOUGLAS DC-10-30	x					x				Improper overhaul of stabilizer chain drive unit, stab frove in flight, no movement in

												response to AP or trim switches
602	11/13/2003	Cessna 208B		x								Pilot taxied behind aircraft doing maintenance runs
562	9/9/2004	Piper PA-32R-300		x								Vacuum pump fail, instrument fail at night pilot doisoriented, crashed
517	6/30/2005	Piper PA-32RT-300		x								Aircraft impacted terrain, pilot did not maintai9n airspeed during initial climb out
242	7/13/2004	Airbus Industrie A320-233	x			x			x			Engine cowl departed aircraft in flight, not properly secured by maintenance
509	7/28/2005	de Havilland DHC-3	x						x			Electrical arcing cut hole in fuel line, cockpit fire, inadequate annual inpection by maintenance
198	5/30/2005	de Havilland DHC-8-202	x								x	Ground support vehicle stuck aircraft during pushback, improper procedures by maint personnel
459	7/11/2006	Cessna 206F		x								Severe downdraft after lift off, collided with terrain
34	3/1/2008	BOEING 737-3H4		x								Failure of the taxiing flight crew to maintain an adequate clearance from the stationary airplane
48	1/8/2008	Boeing 737-2H4	x			x		x				Total hydraulic failure, LG swivels improperly installed
576	5/2/2004	Cessna U206F		x								Loss of directional control for an undetermined reason during takeoff-initial climb, which resulted in the left wing colliding with the ground
565	8/26/2004	Piper PA-18		x								Collision with a rock and subsequent main landing gear

												collapse during the landing roll
158	11/28/2005	McDonnell Douglas MD-10		x								Aircraft struck unused stairs
54	12/2/2007	Bombardier, Inc CRJ1		x								Near miss intersecting runways, one landing, one taking off
605	11/4/2003	Cessna 208B		x								Icing, hard landin
645	1/20/2003	Cessna 207A		x								Engine fail for fuel starvation on takeoff, forced landing into trees, pilot inadequate fuel management
99	12/26/2006	BOEING 737-3A4		x								Pilto of taxiing aircraft struck stationary aircraft
608	10/15/2003	Beech A36		x								Fuel nozzle came loose, engine manufacturer delete loctite requirement fron installation instructions
61	9/28/2007	MCDONNELL DOUGLAS DC-9-82 (MD-82)	x				x					Inflight engine fire caused by maint personnel inappropriate manual start procedures left valve in uncommanded open position
236	8/19/2004	Boeing 737-7H4		x								Near miss on goarround with aircraft on taxiway
591	12/20/2003	Cessna 208B		x								Pilot took off with ice on wings, lost control
540	12/15/2004	Piper PA-31-350		x								Misjudged distance/speed while on final approach to land, which resulted in an overrun during the landing roll
388	3/10/2008	CESSNA 402C		x								Fuel leak, loss of power to both engines, air introduced into fuel feed
141	3/15/2006	Boeing 757-222		x								Mountain wave turbulence
546	11/30/2004	Mitsubishi MU-2B-60			x							Bad address

531	2/28/2005	Helio H-295		x								Pilot delayed go around execution, hit trees
464	5/22/2006	de Havilland DHC-2		x								Takeoff in heavy weather, float hit swell and was damaged
301	6/13/2003	Bombardier CL-600-2B19		x								Simultaneous failure of both horizontal stabilizer trim channels on two separate occasions for undetermined reasons
394	1/16/2008	AERO COMMANDER 500B		x								Loss of control due to spatial disorientation
586	2/10/2004	Cessna 208B		x								Crosswind on takeoff, collision with terrain, nose over, icy conditions, pilot failed to abort takeoff
15	8/14/2008	EMBRAER EMB-145LR		x								Excessive pitch on flare tailstrike
130	5/18/2006	McDonnell Douglas MD-83		x								Delayed go around after missed approach, wingtip struck ground
465	5/14/2006	Cessna 207		x								Airplane sturck by villager's sled in AK
368	6/30/2008	CESSNA TR182		x								Engine failure due to fatigue failure of crankshaft
51	12/16/2007	BOMBARDIER CL600-2B19		x								High sink rate, stall, hard landing
359	9/1/2008	CESSNA 207		x								In AK pilot added power on approach to avoid rough terrain at approach end of field, landed long ran into rough
630	4/18/2003	Mitsubishi MU-2B-60		x								Poor vis, pilot lined up with runway edge instead of centerline
327	3/16/2003	Embraer EMB-120ER		x								Failure to maintain directional control during takeoff, snow fog, and distrated crew
428	5/1/2007	Cessna A185F		x								Main landing gear attachment bolts to the right ski sheared during the landing roll in deep snow, resulting in a nose down, and structural damage to the right wing

												and aileron
22	6/28/2008	Bombardier, Inc CL-600-2B19	x								x	Tug driver did not respomnd to wingwalker's signal to stop, struck another aircraft
88	3/29/2007	McDonnell Douglas DC-9-83 (MD-83)		x								Loss of hyd fluid, separation of a B-nut on the rudder power hydraulic shut off valve for undetermined reasons
568	8/13/2004	Cessna U206G		x								Failure to maintain clearance with the powerlines on final approach which resulted in a hard landing
442	1/7/2007	Cessna 207		x								Collision with a snow berm with the left main landing gear, and subsequent damage to the right wing
417	8/5/2007	Beech E90B		x								Failure to maintain clearance from terrain due to spatial disorientation
304	6/7/2003	Beech 1900D	x						x			Failure of the aileron sprocket assembly at the sprocket-to-shaft braze joint,improper inspection procedure utilized by the operator's maintenance personnel
559	9/20/2004	de Havilland DHC-2		x								AK aircraft missing
271	11/29/2003	Boeing 737-3M8		x								Restricted movement of the flight control yoke and tiller wheel steering for reasons undetermined
24	6/28/2008	BOEING 767		x								The design of the supplemental oxygen system hoses and the lack of positive separation between electrical

												wiring and electrically conductive oxygen system components
174	8/29/2005	Bombardier, Inc DHC-8-202		x								Airbus bambardier ground collision
633	4/9/2003	Short Brothers SD3-30		x								Failure to maintain the proper glidepath during the instrument approach, failure to perform go-around Low ceiling and reduced visibility due to mist
635	4/7/2003	Cessna TU206 G		x								Runway incursion by vehicle
646	1/4/2003	Hawker Siddeley HS-125-700A		x								Overheated and burned venturi fan motor
311	5/20/2003	Boeing 757-223	x								x	Unattended CFR vehicle, driver's failure to deploy the parking brake or use wheel chocks to secure the vehicle prior to leaving it unattended
524	4/20/2005	Cessna T210N	x			x						An airborne fire which was fueled by leaking hydraulic fluid (the ignition source for the fire was undetermined) from the landing gear hydraulic system located under the cockpit instrument panel due to inadequate maintenance from other maintenance personnel
212	3/6/2005	Boeing 757-232		x								First officer's misjudgment of a perceived threat, which resulted in the captain's excessive braking and subsequent injury to a flight attendant
41	2/13/2008	Bombardier, Inc CL-600		x								Captain and first officer inadvertently falling asleep during the cruise phase of flight

299	6/23/2003	Boeing 757-232		x								Torching of the right engine caused by an abnormally high flow fuel during engine start for undetermined reasons
566	8/18/2004	Cessna 750		x								MLG failure caused by manufacturer defect
491	11/16/2005	Aero Commander 500B		x								Clearance not maintained with terrain during a nonprecision approach
488	12/13/2005	Cessna 208B		x								Pilot's inadequate compensation for gusting crosswind conditions, which resulted in the airplane exiting the runway, encountering snow, and the nose gear collapsing
362	8/19/2008	Cessna U206G		x								Misjudged speed and distance during takeoff, which resulted in the float-equipped airplane colliding with a bank
79	5/18/2007	DOUGLAS DC-9-31	x								x	Baggage tug struck aircraft, not reported by ground crew
493	11/9/2005	Piper PA-23-160		x								Physical impairment of the pilot
430	4/26/2007	Cessna 310R		x								Pilot's inattentiveness to the fuel flow and fuel selector valve position resulting in fuel starvation
65	7/11/2007	Boeing 757-232		x								Runway incursion by aircraft
291	8/16/2003	Boeing 737-800		x								Turbulence
67	7/10/2007	Boeing 737-232	x								x	Mechanic fell from aircraft, boarding stairs removed by ground personnel
339	1/11/2003	Boeing 757-222		x								Arcing wires in the lavatory sensor that resulted in the subsequent fire
32	3/26/2008	Raytheon Aircraft Company 1900D		x								Flight crew's lack of professionalism and deviation from standard operating procedures, did not see door light

												was illuminated prior to departure
9	11/16/2008	DeHavilland DHC-8-311		x								Mechanical overload of the nosewheel steering links for undetermined reasons
272	11/14/2003	Boeing 747-422		x								Tail strike due to a combination of the wind shifting from a headwind to a tailwind during rotation, and the pilot's control inputs for the crosswind condition
238	8/7/2004	Boeing 737-500		x								Inaccurate radar information due to the failure of the Airport Movement Area Surveillance radar resulting in the tower calling for the airplane to abort the takeoff, subsequently causing tire and brake damage to the airplane
487	12/15/2005	Piper PA-23-250		x								Failure to maintain directional control during the takeoff run A factor was the snow-covered runway
637	3/18/2003	Cessna 208B			x							Bad address
606	11/1/2003	Fairchild Swearingen SA227BC		x								Failure to maintain directional control during the landing roll Contributing factors include the pilot's improper in-flight planning/decision, the icy, snow covered runway and the snow bank
563	9/8/2004	Cessna 402C		x								Improper decision to abort the takeoff with insufficient runway remaining A factor was the wet runway
504	8/29/2005	Cessna 172		x								Inadequate compensation for wind conditions during takeoff-initial climb, which resulted in a loss of control, and subsequent in-flight collision with a creek

478	2/8/2006	Swearingen SA-226-TC		x								Inflight loss of control following a reported fuel asymmetry condition for undetermined reasons
455	8/1/2006	de Havilland DHC-2 MK 1		x								Failure to abort the takeoff at his predetermined reference point, which resulted in a collision with the shore during takeoff-initial climb
522	5/23/2005	Piper PA-18		x								Pilot's selection of unsuitable terrain for landing in AK, which resulted in an overrun
288	8/24/2003	Boeing 757-223	x						x			Failure of maintenance personnel from the aircraft operator to identify a missing left main landing gear truck beam shield and damage to the left main landing gear truck beam which resulted in the fracture of the truck beam as a result of stress corrosion cracking
626	5/30/2003	deHAVILLAND DHC-2		x								Failure to retract the landing gear wheels of an amphibious float equipped airplane after departure from a paved runway, which resulted in a nose over when the airplane was landed on a nearby lake with the wheels extended
643	1/28/2003	Mitsubishi MU-2B-60		x								Bank couriers inadequate visual lookout, as he approached an airplane with operating engines A factor was the lack of guidance and training from the bank, for working around airplanes with operating engines

450	10/13/2006	Cessna 207		x								Pilot's misjudgment of distance/altitude during the landing approach, which resulted in an undershoot and in-flight collision with a river embankment
356	9/19/2008	BOMBARDIER INC CL-600-2C1		x								Near collision on runway
532	2/15/2005	Cessna 207		x								Pilot's failure to maintain directional control of the airplane during the landing roll, which resulted in a departure from the runway and collision with a snow bank
199	5/28/2005	McDonnell Douglas DC-9-82		x								Swerve off runway reason for the occurrence was not determined
461	6/8/2006	Cessna TU206G		x								Pilot's VFR flight into IMC and his subsequent failure to maintain terrain clearance
536	1/14/2005	Cessna U206F		x								Pilot not identifying unsafe landing conditions, and his subsequent intentional swerve during the landing roll resulting in impacting a ditch
269	12/14/2003	Canadair CL-600-2B19	x								x	Tug struck aircraft, operator lost control
644	1/23/2003	Cessna 402C		x								Collided with terrain loss of engine power in the left engine for undetermined reasons
382	4/11/2008	Cessna 310Q	x					x				Rt MLG collapse, mechanic's incorrect reassembly of the landing gear
115	9/5/2006	Boeing B757-232		x								Autoland deviated off center, prolonged flare to recover, landed long, first officer's inadvertent application of full nose-up trim during a prolonged flare

312	5/8/2003	Canadair CL-600-2B19		x								Manufacturer failed to provide adequate procedures for maintenance personnel, vibration caused by worn aileron linkage
396	1/14/2008	Hawker Beechcraft Corporation 1900C		x								Pilot flew into water on approach, spatial disorientation
151	12/20/2005	Boeing 717-200		x								Wheel bearing fail, water dilution of grease, design of hub cap
466	4/25/2006	Cessna 172			x							Bad address
42	2/3/2008	de Havilland DHC-8-202			x							Bad address
386	3/20/2008	Piper PA-31-350	x			x			x			LG failed to extend, failure of company maintenance personnel to install the upper pivot bolt through the pivot hole in the upper end of the landing gear actuating rod, and the company maintenance inspector's inadequate inspection of the work performed
302	6/12/2003	Boeing MD-82		x								Turbulence
408	10/7/2007	de Havilland DHC-2		x								Pilot's inadequate compensation for gusty wind conditions during the final approach to land
325	4/1/2003	Boeing 747-422	x						x			Failure of company maintenance personnel to fully comply with published maintenance/inspection procedures, as well as the resulting inoperative drain heaters and restricted movement of the aileron control cables
207	4/29/2005	Boeing 737-700		x								Moderate turbulence

313	5/7/2003	Bombardier CL-600-2B19	x								x	Belt loader struck aircraft
413	9/3/2007	de Havilland DHC-2 MK1		x								Pilot's inadequate compensation for wind conditions while water taxiing
329	3/13/2003	Dornier 328-300		x								Lightning
235	8/27/2004	Boeing 757-200		x								Birdstrike
555	9/29/2004	Cessna 208B		x								Pilot's inadequate preflight preparation, and his subsequent selection of a runway for takeoff that was listed as out of service, resulting in a collision with barricades and uneven terrain during takeoff
297	7/17/2003	Boeing B777-222		x								Turbulence
601	11/18/2003	Fairchild Swearingen SA226TC	x				x					The operator's improper maintenance and servicing of the airplane's nose landing gear assembly, resulting in the collapse of the nose landing gear during the landing roll
337	1/16/2003	Boeing 737-83N	x								x	Aircraft under tow struck deice truck, ground tow personnel not maintaining clearance from the de-icing vehicle during the tow back to the gate
87	4/7/2007	Canadair CL-600-2B19	x					x				In-flight separation of the left engine thrust reverser translating cowling due to intermittent binding and jamming of the reverser on the accident flight and on previous flights Contributing factors were the inadequate maintenance

												action by the operator due to their failure to properly resolve the prior reverser malfunctions
578	4/18/2004	Piper PA 28-161		x								Pilot's continued flight into adverse weather conditions that resulted in an in-flight collision with mountainous terrain

Appendix F:

Chi-Square Analysis

			ACCIDENT			TEST STAT	CHI DIST	w
			MR	NMR				
US	PRE	OBS	31.00	107.00	138.00			
		EX	27.00	111.00	138.00			
		PCENT	0.22	0.78	1.00			
		RES	4.00	-4.00	0.00			
	POST	OBS	23.00	115.00	138.00			
		EX	27.00	111.00	138.00			
		PCENT	0.17	0.83	1.00			
		RES	-4.00	4.00	0.00			
	TOTAL	OBS	54.00	222.00	276.00	1.47	0.225	.103
		EX	54.00	222.00	276.00			
		PCENT	0.20	0.80	1.00			
		RES	0.00	0.00	0.00			
UK	PRE	OBS	37.00	101.00	138.00			
		EX	33.00	105.00	138.00			
		PCENT	0.27	0.73	1.00			
		RES	4.00	-4.00	0.00			
	POST	OBS	29.00	109.00	138.00			
		EX	33.00	105.00	138.00			
		PCENT	0.21	0.79	1.00			
		RES	-4.00	4.00	0.00			
	TOTAL	OBS	66.00	210.00	276.00	1.27	0.259	.096
		EX	66.00	210.00	276.00			
		PCENT	0.24	0.76	1.00			
		RES	0.00	0.00	0.00			
1995-2000	UK	OBS	37.00	101.00	138.00			
		EX	34.00	104.00	138.00			
		PCENT	0.27	0.73	1.00			
		RES	3.00	-3.00	0.00			
	US	OBS	31.00	107.00	138.00			
		EX	34.00	104.00	138.00			
		PCENT	0.22	0.78	1.00			
		RES	-3.00	3.00	0.00			
	TOTAL	OBS	68.00	208.00	276.00	0.70	0.402	.071
		EX	68.00	208.00	276.00			
		PCENT	0.25	0.75	1.00			
		RES	0.00	0.00	0.00			

2003-2008	UK	OBS	29.00	109.00	138.00			
		EX	26.00	112.00	138.00			
		PCENT	0.21	0.79	1.00			
		RES	3.00	-3.00	0.00			
	US	OBS	23.00	115.00	138.00			
		EX	26.00	112.00	138.00			
		PCENT	0.17	0.83	1.00			
		RES	-3.00	3.00	0.00			
	TOTAL	OBS	52.00	224.00	276.00	0.85	0.356	.079
		EX	52.00	224.00	276.00			
		PCENT	0.19	0.81	1.00			
		RES	0.00	0.00	0.00			