AIRLINE MAINTENANCE OUTSOURCE STRATEGY AND AVIATION SAFETY

by

Linfeng Jin

A Dissertation

Submitted to the Faculty of Purdue University
In Partial Fulfillment of the Requirements for the degree of

Doctor of Philosophy

School of Aviation and Transportation Technology
West Lafayette, Indiana
August 2021

THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Chien-tsung Lu, Chair
School of Aviation and Transportation Technology

Dr. Yi Gao
School of Aviation and Transportation Technology

Dr. John Michael Davis
School of Aviation and Transportation Technology

Wei Zakharov
Libraries & School of Information Studies

Approved by:
Dr. Kathryn Newton

This dissertation is dedicated to aircraft maintainers who work at airlines, repair stations, and shops around the world for shedding blood, sweat, and tears in countless day and graveyard shifts, under extreme conditions of heat and cold, humid and dry environments. They are unsung heroes, and the general public may never know what they do, but all owe a debt of gratitude to them for their tireless work.

ACKNOWLEDGMENTS

This Ph.D. dissertation writing journey was by no means a solo flight.

First of all, my completion of this degree program would not have been possible without the active and ongoing support of my family. My father: 金华苗 (Huamiao Jin) and my mother: 邵照君 (Zhaojun Shao) who raised me in a kind and just family. Family is where all my story begins. They have always boosted my confidence when I needed encouragement and tempered me when I was too enthusiastic.

Secondly, I need to express my gratitude to my advisor Dr. Chien-tsung Lu for his constant support and many meaningful conversations, who guides me to conduct research and provide life wisdoms.

I also must extend my appreciation to Dr. Yi Gao for his incessant push for a better academic writing and his advice on professionalism, Dr. John Michael Davis for his comments on aircraft maintenance oversight and diligent effort to connect with industry interviewees, Dr. Wei Zakharov for her advice on using the library system, academic information search, and help on connecting with Chinese library resources.

I could not have finished the second part of this research without eight interviewees who generously spent hours with me sharing their opinions on airline maintenance outsourcing and giving me feedback on the stage 1 results. They deserve more recognition, but I am limited by ethical considerations.

“A journey of a thousand miles begins with a single step.” All my work and education experiences and all the people I have met in the U.S. and China have made me who I am today. I am grateful to all these people and places named and unnamed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DEFINITIONS

Accountable manager: "The person designated by the certificated repair station who is responsible for and has the authority over all repair station operations that are conducted under part 145, including ensuring that repair station personnel follow the regulations and serving as the primary contact with the FAA" (E-CFR, 2002a, § 145.3)

Air carrier: "Air carrier, large certificated. An air carrier holding a certificate issued under 49 U.S.C. 41102, as amended, that: (1) Operates aircraft designed to have a maximum passenger capacity of more than 60 seats or a maximum payload capacity of more than 18,000 pounds; or (2) conducts operations where one or both terminals of a flight stage are outside the 50 states of the United States, the District of Columbia, the Commonwealth of Puerto Rico and the U.S. Virgin Islands" (E-CFR, 2002b, § 241.03). In this research, "air carrier" is interchangeable with "airline."

Aircraft accident: "An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage" (E-CFR, 2010, § 830.2).

Aircraft incident: "An occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations" (E-CFR, 2010, § 830.2).

Airplane: "An engine-driven fixed-wing aircraft heavier than air, that is supported in flight by the dynamic reaction of the air against its wings" (E-CFR, 1962, § 1.1).

Block hours: "Time from the moment the aircraft door closes at departure of a revenue flight until the moment the aircraft door opens at the arrival gate following its landing; block hours are the industry standard measure of aircraft utilization" (Massachusetts Institute of Technology, 2018).

Hazard: "A condition that could foreseeably cause or contribute to an aircraft accident (Federal Aviation Administration, 2017, p. A-1).

Low cost carrier (LCC): An air carrier that adopts a relatively low-cost structure in comparison with other comparable carriers and offers low fares and rates (Bennett & Craun, 1996).

Maintenance: "Inspection, overhaul, repair, preservation, and the replacement of parts, but excludes preventive maintenance" (U.S. Government Publishing Office, 1962, § 1.1).

Major air carrier: "Any air carrier with the annual operating revenue is over $1 billion" (U.S. Government Publishing Office, 1962, § 1.1).

Risk/ safety risk: "The composite of predicted severity and likelihood of the potential effect of a hazard" (Federal Aviation Administration, 2017, p. A-2).

Safety: "The state in which the risk of harm to persons or property damage is acceptable" (Federal Aviation Administration, 2017, p. A-2).

Safety Management System (SMS): "It is a formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk" (Federal Aviation Administration, 2015, p. 8).

Serious injury: "Serious injury means any injury which: Requires hospitalization for more than 48 hours, commencing within 7 days from the date of the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface" (E-CFR, 2010, § 830.2).

Substantial damage: "Damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component. Engine failure or damage limited to an engine if only one engine fails or is damaged, bent fairings or cowling, dented skin, small punctured holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wingtips are not considered substantial damage for the purpose of this part" (E-CFR, 2010, § 830.2).

Offshoring: "Relocation of organizational activities to a wholly owned subsidiary or an independent service provider in another country" (Oshri et al., 2015, p. 8).

Outsource: "Contracting with a third service provider for the management and completion of a certain amount of work, for a specified length of time, cost, and level of service" (Oshri et al., 2015, p. 8).

LIST OF ABBREVIATIONS

A&P - Airframe and Powerplant

14 CFR - Title 14 of the Code of Federal Regulations

Airline Consumer Action Project - ACAP

ALPA - Air Line Pilots Association

AMFA - Aircraft Mechanics Fraternal Association

APU - Auxiliary Power Unit

ARSA - Aeronautical Repair Station Association

ASI - Aviation Safety Inspector

ATOS - Air Transportation Oversight System

BASA - Bilateral Aviation Safety Agreement

BEA - Bureau of Economic Analysis

BIS - United Kingdom Department for Business, Innovation and Skills

BTS - Bureau of Transportation Statistics (as part of DOT)

CASS - Continuing Analysis and Surveillance System

CG - Center of Gravity

CMO - Certificate Management Office

COMAT - Company Material

CPUSA - Communist Party of the United States of America

DoD - Department of Defense

DOT - United States Department of Transportation

FAA - United States Federal Aviation Administration

FAPD - Fatalities per hundred thousand departures

FAPM - Fatalities per million revenue miles

FE - Fixed Effects

FGLS - Feasible General Least Squares

FSDO - Flight Standards District Office

GAO - United States General Accounting Office (since July 2004, Government Accountability Office)

GPO - United States Government Printing Office

HMV - Heavy Maintenance Visit

IAMAW/IAM - International Association of Machinists and Aerospace Workers

IATA - International Air Transport Association

IBT - International Brotherhood of Teamsters

IBT - International Brotherhood of Teamsters

IFO - International Field Office

IID - Independently Identically Distributed

IRB - Institutional Review Board

LCC - Low Cost Carrier

LM - Lagrange Multiplier

LSDV - Least Squares Dummy Variable

MCTG - Maintenance Cost Technical Group

MEL - Minimum Equipment List

MIT - Massachusetts Institute of Technology

MRO - Maintenance, Repair and Overhaul

MtA - Airline Maintenance Labor to Aircraft Ratio

N/A - Not Applicable

NOPF - Net Operating Profits

NTSB - National Transportation Safety Board

OIG - Office of Inspector General

Omx - Percent of Maintenance Expenses Outsourced

OPF - Operating Profits

QMS - Quality Management System

RE - Random Effect

RMSE - Root Mean Square Error

SA - Safety Assurance

SARP - Standards and Recommended Practice

SAS - Safety Assurance System

SB - Service Bulletin

SEC - U.S. Securities and Exchange Commission (SEC)

SEP - Surveillance and Evaluation Program

SMART - Structural Modifications and Repair Technicians Inc.

SMM - Safety Management Manual

SMS - Safety Management System

SPAS - Safety Performance Analysis System

SRM - Safety Risk System

SSE - Error Sum of Squares

SUP - Suspected Unapproved Part

SWA - Southwest Airlines

TWU - Transport Workers Union of America

U.S. - United States of America

ABSTRACT

Airline maintenance outsourcing is a common practice in the deregulation era of airline industry, and it mainly covers topics across technology, economics, and politics. This dissertation used an explanatory sequential mixed methods research to explore the effect of airline maintenance outsource on aviation safety. The first stage of the research was a quantitative research using a panel data analysis using five models to explore the statistical relationships between the independent variables: amount of outsourced maintenance, airline profitability, and real gross domestic product per capita, and dependent variables: aircraft accident rate and aircraft incident rate for the major U.S. Part 121 passenger air carriers between 1995 and 2019. The second qualitative research was interview with commercial aircraft maintenance professionals, airline manager, civil aviation regulators, and other key stakeholders to seek their interpretation about the first stage research results, opinions and understandings about the current commercial aircraft maintenance practice, and their expectations of the industry. Both stages of research confirmed that airline maintenance outsourcing does not affect aviation safety, and there is a positive relationship between airline financial performance and aviation safety performance. Consequently, airline maintenance outsourcing is not only economically sensible but also conducive to aviation safety if it is done properly. In the second stage research, the researcher found deficiencies in the current oversight system mainly due to lack of funding and personnel which needs to be addressed. The researcher recommended activity-based accounting to solve the funding issues about airline maintenance oversight and the future study can focus on decision-making process for airline maintenance outsourcing/insourcing based on empirical data.

CHAPTER 1. INTRODUCTION

Overview

With the ever-increasing interconnectedness of the global economy and the technical advancements of the aerospace industry, there has been a marked increase in commercial aviation activities worldwide (Jorge-Calderon, 2016). Several factors are influencing this unprecedented growth of the global airline industry including domestic and global economic expansion, political and cultural conditions, public health, and many other elements (Belobaba et al., 2016; Bogoch et al., 2015; Bruce et al., 2018; Sobieralski, 2020). A legal change of significance to this growth took place in 1978 U.S. President Jimmy Carter signed the Airline Deregulation Act into law, which prompted the federal government of the United States to remove restrictions on the fares, routes, and market entry of new airlines which created a relatively free market for flight passengers and airline traffic in general (S.2493 - 95th Congress (1977-1978), 1978; Wensveen, 2011). One of the most positive ramifications of this deregulation was that more and more passengers could afford air travel because of lower ticket prices (Airlines for America, 2018; Goetz & Vowles, 2009).

On the other hand, today's global airlines have been striving to find ways to increase profits and cut costs so that they can survive the oscillations of economic and political shifts (Belobaba et al., 2016; Bruce et al., 2018; Graham et al., 1983). As one of the proven ways to reduce operational (labor) costs, the major airlines have increasingly outsourced their aircraft maintenance to third party aircraft maintenance providers; this practice is known as contract maintenance (Callaci, 2020; Czepiel, 2003; McFadden & Worrells, 2012). Massachusetts Institute of Technology (MIT) collected and analyzed the data provided by the U.S. Department of Transportation Form 41 (U.S. DOT Form 41of the Bureau of Transportation Statistics (BTS), and relevant filings to the Securities and Exchange Commission (SEC). The data showed a trend of increased costs for airline maintenance unit labor, total aircraft maintenance, and contract maintenance among the U.S. major passenger airlines between 1995 and 2018 (Massachusetts Institute of Technology, 2020).

Another part of this picture, several fatal crashes of Part 121 airline jets have concurred with the increasing trend of the U.S. airline maintenance outsource over the last thirty years; the primary contributors to these accidents being poor maintenance work by the outsourced MRO providers and a lack of regulatory oversight from the Federal Aviation Administration (FAA) and the airlines (National Transportation Safety Board, 1996, 2004; Quinlan et al., 2013). Having observed the increasing trend of airlines to outsource aircraft maintenance, coupled with worsening safety records, U.S. governmental watchdogs such as the Governmental Accountability Office (GAO) and the Office of Inspector General (OIG), along with unions, academia, and flight passengers advocate groups have expressed concerns over the negative consequences of airline maintenance outsourcing on aviation safety (Business Travel Coalition, 2008; Government Accountability Office, 1997, 2003a, 2004, 2010, 2012; McFadden & Worrells, 2012; Office of Inspector General, 2002, 2005b; *Putting U.S. Aviation at Risk: The Impact of the Shutdown*, 2019; Quinlan et al., 2013; Transport Workers Union of America, 2018).

Problem Statement

The problem addressed by this research is the effects of passenger airline aircraft maintenance outsource on aviation safety of passenger airlines.

Purpose

The purpose of this research aims to study the effects of passenger airline maintenance outsource on aviation safety of passenger airlines via the explanatory sequential mixed methods research. The first stage of the research was a quantitative research using a panel data analysis to explore the statistical relationships between the variables related to airline maintenance outsourcing identified and the variation of safety performance metrics for the FAA major Part 121 passenger air carriers between 1995 and 2019. The second stage qualitative research involved the interviews with commercial airline maintenance industry professionals and stakeholders to seek their interpretation about the first stage research results, opinions and understandings about the current commercial aircraft maintenance practice, and their expectations of the industry in more depth by semi-structured interview.

Research Questions

1) What variables related to aircraft maintenance outsource might contribute to the variation of safety performance metrics for the FAA major Part 121 passenger air carriers?

2) What are the commercial aircraft maintenance industry and related stakeholders’ views on airline maintenance work outsourcing and airline aircraft safety?

Limitations

1) The NTSB database does not list every airline incident.
2) Limitation of the NTSB database: for most of accident/incident reports, few aviation accidents and incidents involve maintenance issues, even fewer differentiate whether the accident/incident resulted from outsourced maintenance or inhouse maintenance.
3) Some independent variables reported by some airlines on DOT form 41 are inaccurate due to missing, invalid, and inconsistent entries.
4) Sampling frequency is yearly rather than quarterly, or monthly which results from the way the raw data are reported.
5) The independent variables may not truthfully capture the effect on accident rate and incident rate.
6) The dependent variables including accident rate and incident rate may not show a comprehensive view of the aviation safety status of airlines.
7) The functional form of all the panel data models may not reflect the true relationship between independent variables and dependent variables.
8) The panel data method has some inherent problem as detailed in Chapter 3.
9) The reliability and validity of the interview instrument is limited by each interview participant’s personal background and cultural settings (Lincoln & Guba, 1985).
10) A subconscious direction occurs as the researcher is an instrument which brings subjectivity into the research (Merriam, 2016).
11) It is hard to build a rapport between interviewer and interviewees from the online interviews compared with on-site interviews (Gubrium et al., 2012).
12) There is always a possibility of breach of confidentiality while using communication tools over the Internet, which in return might decrease the credibility of interviewees’ response (Merriam, 2016).
13) The interviewees are found via the snowball sampling technique.

Delimitations

1) The first stage of this research (quantitative part) only included eight FAA major Part 121 passenger air carriers that have been continuously operating between 1995 and 2019: Alaska Airlines, American Airlines, Delta Air Lines, Frontier Airlines, Hawaiian Airlines, Southwest Airlines, Spirit Airlines, and United Airlines.
2) The second stage of this research (qualitative part) included interviews of the commercial aircraft maintenance professionals and stakeholders who live and work in the U.S. or East Asia.

Significance

The significance of this study hinged upon mixed methods research to explore the effects of airline maintenance outsource on aviation safety. Mixed methods research enables the researchers to tackle the issue in a more comprehensive way because mixed methods research allows the researchers to bridge the adversarial gap between quantitative and qualitative research and understand the research problem through naturalistic multiple worldview paradigms (Creswell, 2018; Lincoln & Guba, 1985). Therefore, the use of mixed methods research to explore the effects of airline maintenance outsource on the aviation safety of passenger airlines in a doctoral dissertation was justified. A detailed description of mixed methods research can be found in chapter 3.

There could be several potential points of significance resulting from the research findings. The first takeaway of this dissertation is to show whether there are statistically significant correlations between these independent variables: amount of outsourced maintenance, inhouse maintenance labor to aircraft ratio, airline inhouse maintenance pay, airline profitability, real gross domestic product per capita, and these dependent variables: aircraft accident rate and aircraft incident rate. This research could provide airline managers with direct numerical results of the relationships between the independent variables and the dependent variables, and a methodology framework to support the decision-making process of planning maintenance activities. This process is difficult, pricy, and strategically significant for airlines' safe and successful operations (Bağan & Gerede, 2019; Bazargan, 2016; McFadden & Worrells, 2012; Porter, 1980, 2008). Furthermore, for the civil aviation regulators, the airlines, and the repair stations, the qualitative results of this dissertation will help them understand loopholes, deficiencies, concerns, barriers as well as opportunities related to outsourced maintenance issues (Ballesteros, 2007; Perrow, 2011; Reason, 1997, 2003; Wiegmann & Shappell, 2003). With a better understanding of the research subject, the aviation regulators, airlines, and repair stations can reallocate their resources in a more cost-effective way which could improve aviation safety and profitability (Batuwangala et al., 2018; House Transportation & Infrastructure Committee, 2019; N. Mankiw & Swagel, 2006; Porter, 1980, 2008; Smith, 1776/2007; *The Federal Aviation Administration's Oversight of Outsourced Air Carrier Maintenance*, 2007). Finally, this dissertation also seeks to establish concrete grounds for possible regulation revisions as well as an update of safety inspection methodology (Bowen et al., 2003; Government Accountability Office, 1997, 2003b, 2020; House Transportation & Infrastructure Committee, 2019; *The Federal Aviation Administration's Oversight of Outsourced Air Carrier Maintenance*, 2007).

Summary

This chapter introduced an overview of the research and outlined the statement of the problem and the purpose of the dissertation. It also specified research questions and set the limitations and delimitations of the study. Finally, this chapter indicated the significance of the study.

CHAPTER 2. LITERATURE REVIEW

Aviation Maintenance

"Maintenance is the action necessary to sustain or restore the integrity and performance of the airplane" (Hessburg, 2001, p. 246). "Maintenance is the process of ensuring that a system continually performs its intended function at its designed-in level of reliability and safety" (Kinnison and Siddiqui, p. 35, 2013) And also the Federal Aviation Regulation has given its definition of maintenance: "Inspection, overhaul, repair, preservation, and the replacement of parts, but excludes preventive maintenance" (U.S. Government Publishing Office, 1962, § 1.1). In this research, aircraft maintenance is defined as, "A system of activities involving inspection, overhaul, repair, preservation, and the replacement of parts or systems of aircraft to maintain safe operation and meet operational needs of aircraft operator."

There are three reasons for aircraft maintenance. For the airlines, maintenance sustains the aircraft in a usable and punctual daily operation to receive revenue (Belobaba et al., 2016; Scheinberg, 2017). For lessees or aircraft owners, maintenance means the retention of the current and future value of the aircraft/asset by minimizing its physical deterioration throughout its life (Lee et al., 2008; Scheinberg, 2017). Finally, it is a mandatory regulatory requirement for the air carriers to keep their aircraft airworthy so that they can meet the requirements of Airworthiness Certificate and Operations Specifications (Holt, 2002; Scheinberg, 2017).

There are three forms of maintenance based on the scope of maintenance activities: light or line maintenance, heavy or base maintenance, and shop or component maintenance. Line maintenance means — (1) Any unscheduled maintenance resulting from unforeseen events; or (2) Scheduled checks that contain servicing and/or inspections that do not require specialized training, equipment, or facilities (U.S. Government Publishing Office, July 5, 2019, § 145.3).

Base or heavy maintenance normally takes place in a hanger and covers a range of checks and MRO activities. Base or heavy maintenance for airlines has a range of 'lettered' checks from a simple A-check to a comprehensive D-Check. The types of checks required depend on the flight hours-airborne time accumulated since the last check, the aircraft age, and the flight cycles (One take-off and one landing is considered one cycle) (Department for Business, Innovation and Skills, 2016). In recent years, airlines have divided the letter check into smaller tasks, this practice has been referred to as the equalized or segmented check or phase check, and this practice helps the airlines distribute the maintenance workload over time and shorten the length of each period of down-time (Ackert, 2010). The content of maintenance in each lettered check or phase of the check is determined by the airlines on an aircraft-by-aircraft basis (Airbus Customer Service, 2018).

Component maintenance involves maintenance on components removed from aircraft such as engines, auxiliary power units (APUs), and seats. The original equipment manufacturers (OEM) or organizations that are approved to carry out maintenance work on a particular component typically carries out the component maintenance (Department for Business, Innovation and Skills, 2016; Government Accountability Office, 2016). Contrary to the retreat from aircraft maintenance in the airline industry, the manufacturers advance their business to the territories to provide technical business support to their customers. This support includes remote engine health monitoring and aircraft/engine leasing services, and the OEM-MRO build service repair centers around the globe to satisfy increasing demands of the MRO (Belobaba et al., 2016; McCue, 2006; McFadden & Worrells, 2012; Porter, 2008; Scheinberg, 2017). McCue's (2006) analysis of the major engine OEM-MRO joint ventures posited three unique advantages as to why OEM should adopt the strategy of OEM-MRO expansion: 1) the engine OEMs possess specialized MRO-related engineering knowledge of the products from the design and production stage; 2) engine OEMs are in the optimal position to feed MRO experience and knowledge to new product development and upgrade their existing products; 3) changes to engine control (FADEC) in recent years makes it easier for OEM to access the technical details of engines through remote engine monitoring and consequently better execute maintenance tasks.

Outsourcing

The founding father of economics Adam Smith (1776/2007) discovered that the division of labor could increase labor productivity thus spur up economic growth. Furthermore, he proposed all the parties used their unique skills and dedicated machinery to do what they do best for mutual benefit instead of making a product or service all by oneself. In an advanced economy, we satisfy most our needs not through what we produce ourselves but through voluntary exchange with others, and wealth is increased when trade is vibrant and free (Butler, 2012; Coase, 1994; Smith, 1776/2007). He wrote the following words, " If a foreign country can supply us with a commodity cheaper than we ourselves can make it, better buy it of them with some part of the produce of our own industry employed in a way in which we have some advantage" (Smith, 1776/2007, p. 350). The scaling down of a country into a company, and it turns into the modern-day concept of outsource. Adam Smith did not oppose government regulation for the public interest, instead he objected to any regulation favoring special interest (Butler, 2012; Coase, 1994; Smith, 1776/2007; Williamson, 1985). Adam Smith asserted, "Nations are never ruined by the prodigality or injudicious of private individuals: only by that of public institutions" (Smith, 1776/2007, p. 342).

Coase (1937) creatively illustrated that a firm must deal with transaction costs (marketing cost in the original text) -a cost in making any economic trade and transaction costs typically include: search and information costs, bargaining costs, keeping trade secrets, policing and enforcement costs, and so on. Coase (1937) offered an economic explanation of emergence of firm, because firm, or any business entity in collective nature is inherently more effective in production and trade exchange than a single bilateral contract could have achieved, and Coase also determined the size/form of a firm is an optimal balance between the competing tendencies of transaction costs and overhead and bureaucracy costs (Royal Swedish Academy of Sciences, 1991). In addition, Coase (1937) discovered that the process of vertical integration of a firm which involves the combination of two or more stages of operations by different collaborative parties would suppress the price mechanism and lead to bigger profit margin.

Standing on the shoulders of giants such as Smith, Coase, Williamson (Williamson, 1971, 1985, 1991, 2008, 2010) founded a new subdiscipline called transaction economics by introducing the analysis of discrete structural alternatives to identify and detail key differences in economic organization. Williamson (1971) found the firm can transcend market not only due to its advantage of technological economies, static market (free of disturbances), but also coordinating potential to overcome market failures by incentives and controls. He found that advantages and disadvantages were present among the three primary forms of economic organization (market, hybrid, and hierarchical), and he observed that vertical integration was often a last resort when all the internal forms of adaption and cooperation within the same firm failed (Williamson, 1985, 1991, 2010). And Williamson considered, " Transaction costs are the economic equivalent of friction in physics" (Williamson, 1985, p. 19). The transaction costs theory is based on the two assumptions of human nature: bounded rationality and opportunism, the former refers to limits on information and calculation ability, in his words to show it is hard for human to understand another human, " The capacity for novelty in the human mind is rich beyond imagination" (1985, p. 58), and the latter refers to willingness to profit at the expense of others (Williamson, 1985).

The contract which governs transaction costs mainly depends on asset specificity, uncertainty and frequency. Asset specificity can be interpreted as a degree which asset is valuable only for specific use and specific exchanging partner, and it appears in the four forms: site specificity, physical asset specificity, human asset specificity, and dedicated assets. Uncertainty comes from intentional uncertainty and unintentional uncertainty, the former often shows in a pleasant way of trickery by shenanigan trading parties, the later comes from lack of communication during the negotiation, and unexpected situations not foreseeable after the signing of contract. Frequency refers to times of transactions. Oliver Williamson (1985) predicted the decision to internalization of transaction (insource) or externalization of transaction (outsource) based on the following criteria:

1) As the asset specificity is low, it is economically sensible to outsource.
2) If the transaction involves high uncertainty, it is economically sensible to integrate.
3) If transaction occurs in higher frequency, it is economically sensible to integrate.

Modern business researchers like Porter (Porter, 1980, 2008) and Quinn and Hilmer (1994) further pointed out that properly planned outsourcing activities allowed company managers to leverage skills and resources most efficiently so that they could focus on core competencies and strategically outsource other activities. By adopting outsourcing practices, the company can maximize its returns by concentrating its resources on the activities it can do best, building up the barriers of entry for potential market competitors and fully utilizing its suppliers' resources, capabilities, and capacity when insourcing is difficult or impossible. A recurring theme in Porter's writing is that business needs to form a strategy thinking based on time dimension, "When assessing the strategic benefits and costs of vertical integration, one must examine them in terms not only of the current environment but also of probable changes in industry structure in the future" (Porter, 1980, p. 314). Airline industry is sensible to economic cycles and new aircraft/engine models manufactured and retirement of older fleet, by adopting an outsourcing strategy, airlines can minimize the impacts of economic waves and tap the benefits of technology changes (Belobaba et al., 2016; Bennett & Craun, 1996; Bourjade et al., 2017; Fischer et al., 2008; Government Accountability Office, 2004; Nader & Smith, 1994; Perrow, 2011).

Globally, the increasing trend of outsourcing and offshoring have been spurred by the following factors: technology advancements in information technologies and transport, skilled but low cost in the emerging third world countries, heavy investments in infrastructure, and an improved environment of many developing countries in terms of business, economy, and politics (Oshri et al., 2015). For technology companies, outsourcing is a winning strategy that allows the management not only to focus on the core business functions to attract and satisfy customers, but also to release the capital and reduce the costs of the support services (Ghobrial, 2005; Schniederjans et al., 2006). Offshoring (outsourcing) fits comfortably within the intellectual framework of comparative advantage built on the insights of Adam Smith and David Ricardo (N. Mankiw & Swagel, 2006).

Airline Maintenance Outsource in the U.S.

Before the 1978 airline deregulation, U.S. airlines did most aircraft maintenance work in-house; between the late 1990s and now, airlines have expediated and expanded the outsourcing process (ticket sales and distribution, aircraft leasing, airport gates, complimentary limousine pick-up, food services, ticketing, baggage handlers, aircraft interior cleaning; in the 1990s towards certain accounting functions, training, reservations, IT, frequent flyer programs, and non-airline functions such as property management). The trend of maintenance outsourcing is higher than other work sectors in airlines (Callaci, 2020; Holloway, 2008; Czepiel, 2003; Rutner & Brown, 1999). The U. S. General Accounting Office (GAO) estimated that nearly half of the U.S. airline maintenance had been outsourced to repair stations (1997). By 2016, outsourced maintenance work was reported at 47% of U.S. airlines' total maintenance spending, representing an astonishing $7.3 billion in expenditures, and some spending as high as 75% of their total maintenance costs on outsourced maintenance (Transport Workers Union of America, 2018).

In general, there are four levels of maintenance work or MRO depending on the proportion of work outsourced: fully integrated, partially outsourced, mostly outsourced, and wholly outsourced (Al-kaabi et al., 2007). Airlines with large, diversified fleets and an extensive route structure tend to adopt the fully integrated MRO model (Al-kaabi et al., 2007). The partially outsourced MRO model is suitable for airlines with a few dissimilar fleet types and can meet a large portion of their needs in-house with a minimum of outsourcing (McFadden & Worrells, 2012). The mostly outsourced model is suitable for the airlines with most of MRO outsourced while keeping critical activities in-house (Al-kaabi et al., 2007). Critical activities are those activities that could affect the daily operation and resulting revenues, and the line maintenance and light maintenance are usually within the category of critical activities (Al-kaabi et al., 2007; McFadden & Worrells, 2012). The wholly outsourced MRO model is for startup airlines without the capital to establish an MRO capability or virtual airlines that choose not to list MRO as a part of their business model (McFadden & Worrells, 2012). "A virtual airline is an airline that has outsourced as many possible operational and business functions as it can, but still maintains effective control of its core business" (Flouris & Oswald, 2012, p. 91). Currently for the U.S. airline maintenance, Czepiel contracted by the FAA (2003) and the OIG (2008) found it is an ubiquitous phenomenon that the U.S. airlines keep line maintenance and light maintenance in-house, and outsource the heavy maintenance and overhauls which require more specialized training and more costly equipment and labor to the MRO providers. In short, the successful capability of line maintenance and light maintenance is the core competency of airline maintenance operation and it could influence the safe operations of the airlines (McFadden & Worrells, 2012; Quinn & Hilmer, 1994; Rhoades et al., 2005).

In recent years, the cost of aircraft maintenance has escalated tremendously; for instance, the International Air Transport Association - Maintenance Cost Technical Group (IATA-MCTG) estimated that airlines around the world have spent $69 Billion on MRO, representing around 9% of total operational costs in 2018 (2019). Historically, the airline industry has had heavy government intervention, although this tendency has generally lessened over the last decades, in some countries airlines are still to some extent protected from failure (Morrell, 2007). Asian countries show the most intervention of airlines. In terms of MRO service, the governments in Asia are striving to attract international airlines to do heavy maintenance visits (HMVs) in Asia even with the advantage of labor cost (Cooper et al., 2019).

Outsourced Maintenance Safety Threats

Contract maintenance providers compete with each other on the basis of cost-reduction and time efficiency(Bağan & Gerede, 2019; Bazargan, 2016; Office of Inspector General, 2008). This may lead them to the implementation of unsafe practices which could impose threats to the quality and safety of maintenance work (Bağan & Gerede, 2019; Quinlan et al., 2013). The disorganization of MRO vendors arises from the fact that repair stations are working on a high volume of aircraft simultaneously, so required parts are often unavailable. As a result, engineers often succumb to quick but risky solutions such as "parts robbing" or use of suspected unapproved parts (SUPs) (Czepiel, 2003; Kinnison & Siddiqui, 2012; Olaganathan et al., 2020). The heavy workload adds extra complexity and difficulty to the maintenance planning process (Albakkoush et al., 2020; Quinlan et al., 2013; Tang & Elias, 2012). There may also be regulatory failures in monitoring ongoing revision changes at repair stations. Foreign repair stations that perform maintenance for their partners of U.S.-based airlines often do not have sufficient oversight from the FAA. (Czepiel, 2003; Government Accountability Office, 1997, 2016; Quinlan et al., 2013, 2014). Finally, the spillover effects are the seemingly unrelated events may have particularly negative impacts on the maintenance work quality (Quinlan, 2012; Quinlan et al., 2013). MRO vendor mechanics are often victims of poor ergonomic and biomechanical working conditions (Asadi et al., 2019). In return, this can affect aviation safety as the aircraft maintenance labor force is a key part of a tightly coupled socio-technical system, the failure of protection of the mechanics could contribute to an accident (Perrow, 2011; Reason, 1997, 2016; Wiegmann & Shappell, 2003). While U.S. Part 121 air carriers have excellent safety records over the past few decades (Belobaba et al., 2016; Van Wagner, 2007), poor performance in terms of on-time departure and arrival statistics may be partly explained by substandard maintenance work performed both in-house and by third parties, and may suggest a future impact to aviation safety (Bağan & Gerede, 2019; CBS 2 News Morning, 2019; Rhoades et al., 2005). In short, the quality of outsourced work is not fully under control of airlines because it is simply not done by airlines themselves-a platitudinous adage to summarize it, "In God we trust. Everyone else we check" (Hessburg, 2001, p. 36). And the gravest consequence for the poor outsourced maintenance is air crash, and some of aviation accidents related to aircraft maintenance outsourcing factors are introduced in the following text.

Selected Fatal U.S. Accidents Involving Contract Maintenance Provider Errors

National Transportation Safety Board

The National Transportation Safety Board (NTSB) founded in 1967 is an independent agency of the U.S. government that investigates all the transportation modes: aviation, highway, marine, pipeline, and railroad modes, as well as accidents related to the transportation of hazardous materials that mainly happen in the United States and provides safety recommendations to the regulators and general public (Bibel, 2008; Cusick et al., 2017; National Transportation Safety Board, n.d.). The NTSB also serves as the first level of appeal in cases of the FAA administrative enforcements of suspension, revocation, and fines (Hamilton & Nilsson, 2015). The main task of the NTSB is to investigate the major traffic accidents via the party system of investigation (Bibel, 2008; Hamilton & Nilsson, 2015).

As one of the smallest federal agencies employing around 300 people, the NTSB always works with other agencies such as the FAA, civil groups such as American Red Cross, corporations such as aircraft manufacturers, and individuals such as industry experts to investigate major commercial accidents (Cusick et al., 2017; Wells, 2001). In the end, the NTSB writes final accident reports containing "probable causes" and makes recommendations to the interested parties such as airport authority, the manufacturers, and most frequently the FAA (Hamilton & Nilsson, 2015). The full-text reports of the following accidents are found in the NTSB database.

Valujet Flight 592 Accident

On May 11, 1996, a Douglas DC-9-32 operated by ValuJet Airlines Flight 592 crashed into the wetlands in the Florida Everglades 10 minutes after takeoff from the Miami International airport. A total of 110 people on board including two pilots, three flight attendants and 105 passengers perished in this accident. The NTSB (1997) identified the probable cause of this accident: there was a fire in a Class D compartment which was a fail-safe, air-tight, and limited cargo compartment.

In the accident report, the NTSB (1997) identified three major interconnected failures contributing to the accident. First, SabreTech, one of the MRO providers for ValuJet, failed to properly prepare, package, and identify 144 unexpended but expired oxygen generators before placing them as COMAT (company material) in the ValuJet Class D cargo compartment. Second, ValuJet failed to properly oversee its contract maintenance program to ensure compliance with maintenance, maintenance training, and hazardous materials requirements and practices. Third, the FAA as a regulator failed to mandate the installation of smoke detection and fire suppression systems in Class D cargo compartments even though seven aviation accidents or incidents involving chemical oxygen generators had occurred within the past ten years (National

Transportation Safety Board, 1997). It is noteworthy that the NTSB (1997) did not find any preexisting mechanical conditions may have contributed to the accident.

Air Midwest Flight 5481 Accident

On January 8, 2003, a fully loaded Beechcraft 1900D with two flight crew and 19 passengers onboard failed to take off and crashed into the Charlotte Douglas International Airport hangar. This flight designated as Air Midwest Flight 5481 was operating as US Airways Express Flight 5481. No one survived the crash, and the whole aircraft was destroyed by the impact and a post-crash fire.

In the investigation report, the NTSB (2004) concluded that the probable cause was the airplane's loss of pitch control during takeoff. The loss of pitch control resulted from the wrong rigging of the elevator control system aggregated by the airplane's aft center of gravity, which was substantially aft of the certified center of gravity (CG) aft limit. The crashed aircraft's elevator control system was incorrectly rigged during the detail six maintenance check, and the incorrect rigging limited the airplane's elevator travel to 7degrees nose down, or about one-half of the downward travel set by the airplane manufacturer.

The NTSB (2004) identified six major contributing causes to the accident. First, Air Midwest's lack of oversight of the work being performed at the Huntington, West Virginia, maintenance station. Air Midwest did not oversee the contractor Raytheon Aerospace and Raytheon Aerospace's subcontractor Structural Modification and Repair Technicians, Inc. Second, Air Midwest's maintenance procedures and documentation were poorly written and hard to follow for the mechanics. Third, Air Midwest's weight and balance program at the time of the accident was wrong and resulted in substantially erroneous weight and balance calculations for Flight 5481. Fourth, the Raytheon Aerospace quality assurance inspectors failed to detect the incorrect rigging work of the elevator control system performed by the Structural Modification and Repair Technicians mechanic who had no previous experience or relevant training in the elevator control rigging on the Beech Model 1900D. Fifth, the FAA average weight assumptions in the Advisory Circular 120-27C, "Aircraft Weight and Balance Control" were outdated and hence below the average weight of the U.S. passengers. Sixth, the FAA failed to oversee Air Midwest's maintenance program and its weight and balance program.

The above two accident reports mainly highlight the technical aspects of risks from the outsourced maintenance, and they touched upon some aspects of individual organizational factors. It is worthwhile to look at interested groups views on airline maintenance outsourcing in a bigger perspective.

Interest Groups' Views on Airline Maintenance Outsourcing

Arline Labor Union

The birth of a labor union replaces private ordering with collective bargaining, and there are three types of unions to raise wages: class unions, craft unions, and industrial unions (Williamson, 1985). Karl Max and Frederick Engels in the *Manifesto of the Communist Party* stated the purpose of the trade unions as the following: " The workers begin to form combinations (Trades' Unions) against the bourgeois; they club together in order to keep up the rate of wages; they found permanent associations in order to make provision beforehand for these occasional revolts" (1848/1969, p. 19). This is a typical example of the class union.

It was no coincidence that Mike Quill, the founder of the Transport Workers Union of America (TWU)-the biggest, and arguably the most influential labor union in U.S. labor history and has absorbed multiple airline labor unions, was a close ally with the Communist Party USA (CPUSA) for the first twelve years of his leadership of the union, and eventually broke apart with the CPUSA for advancing the interests of the TWU over other political agendas (Lichtenstein, 1998; Meier & Rudwick, 1982).

In the modern U.S. airline industry, unions are more likely to fall under the group of craft unions such as pilots, mechanics unions and industry unions such as service agent unions (Government Accountability Office, 2003b; Wensveen, 2011). These unions serve two functions: the agency function, mainly as an informant for members, and the governance function to negotiate benefits in a selective fashion (Williamson, 1985).

In the United States, the national union membership rate, the percent of wage and salary workers who are members of unions, has been showing a declining trend: 10.3% in 2019 (Bureau of Labor Statistics, 2020). The airline industry shows a contrasting picture Hirsch and Macpherson (2020) estimated that the air transportation union membership rate was 37.1% in 2019. Almost every major airline has a maintenance union (Government Accountability Office, 2003b).

Table 1 Mechanics and Related Unions at Major Passenger Airlines as of February 2003

Airline	Mechanics and related
Alaska	AMFA
America West	IBT
American	TWU
Continental	IBT
Delta	(None)
Northwest	AMFA
Southwest	AMFA
United	IAM
US Airways	IAM

Note. Adapted from “Airline Labor Relations: Information on Trends and Impact of Labor Actions,” by Government Accountability Office, 2003, p. 5. Copyright 2003 by Author.

One great strength that one union can impose on airline management is their collective bargain through their strike threat (Chaison, 2007; Hirsch, 2006). In the U.S., the collective bargain is governed through the Railway Labor Act (Government Accountability Office, 2003b; Wensveen, 2011). It has three intentions: minimize the disruption of commerce in the travel industry in the resolution of labor disputes, maintain the status quo in terms of objective work conditions and practice, and prohibit either side from interfering with, influencing, or coercing counterpart choice of representatives (Government Accountability Office, 2003b). A detailed collective bargain process is provided below.

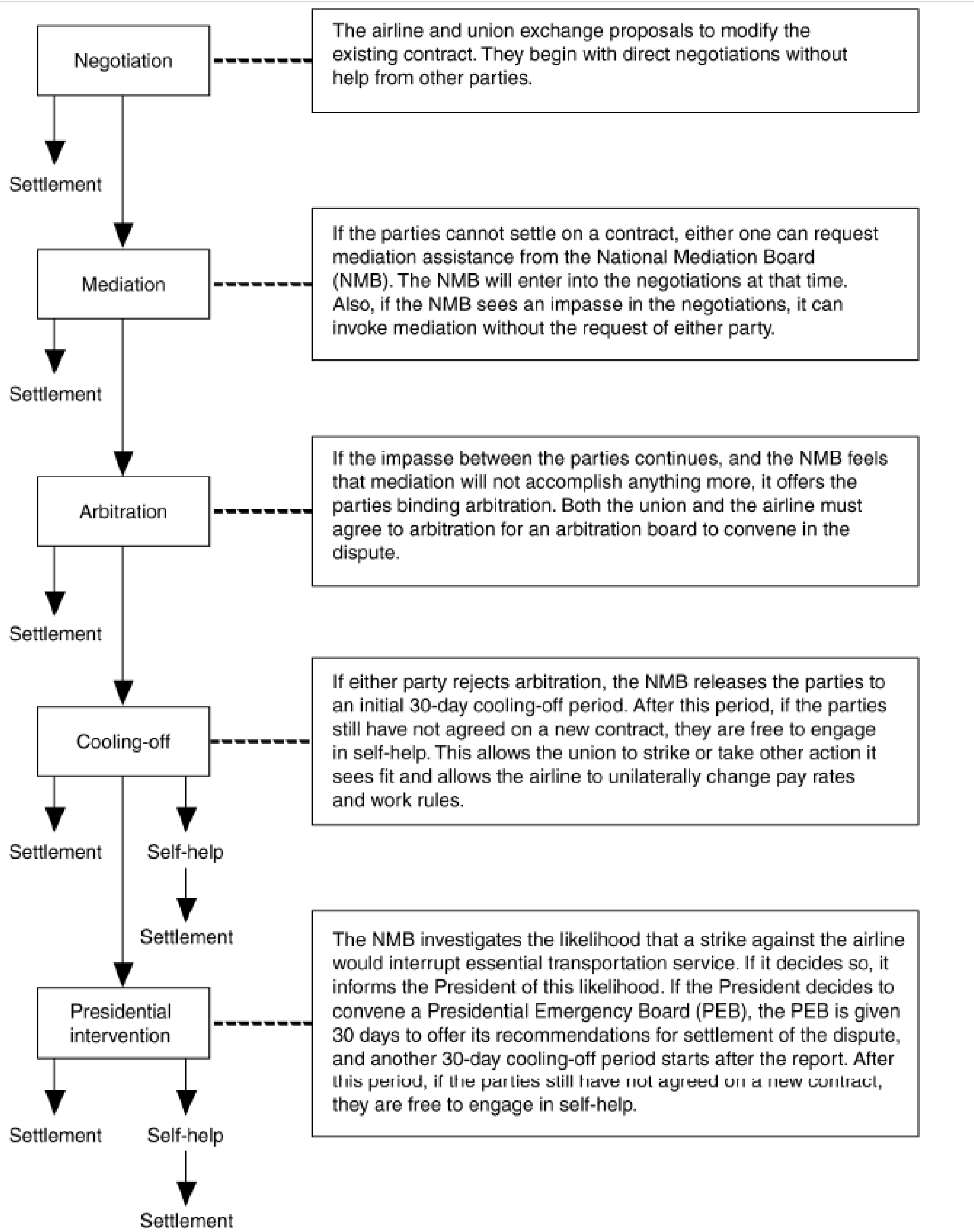

Figure 1. Collective Bargaining Process under the RLA

Note. Adapted from "Airline Labor Relations: Information on Trends and Impact of Labor Actions" by the Government Accountability Office, 2003

Card (1996) found that the average union mechanic contract wage stayed relatively flat between 1980 and 1987, but it dropped 10 percent from 1987 and 1995. This drop was also reflected in the nonunion mechanic contract due to fierce competition and the downturn of economic cycles.

In recent years, most of the debates involving airline unions concentrated on whether they hurt the airlines' efficiency and profitability (Gittell et al., 2004; Greer, 2009; Hirsch, 2006). Greer (2009) found that the impact of the union on airline efficiency is statistically insignificant through data envelopment analysis and tobit regression analysis. Using historic data, Gittell et al. (2004) suggested that the airline union representations had generated higher wages, and the unions brought about enough productivity improvement to offset the costs of these higher wages. Hirsch (2006) used historic data to show that unions have strong bargaining power to increase wages, but wages are also negatively affected by poor financial performance of airlines due to cycles of the economy or black swan incidents such as the September 11 terrorist attack; also union contracts prevent the cross-mobility of equivalently skilled labor and create a non-competitive wage structure among airlines.

On the safety side, the airline labor unions have done positive things to advocate and improve aviation safety. Zapf (2014) investigated 15 major US commercial airlines between 1990 and 2013, and she found these mean safety metrics: the number of accidents and incidents divided by the total departures of unionized airlines is higher than their non-unionized counterparts, but there was no statistically significant difference between two groups of airlines and the unions studied were only pilot unions and flight attendant unions. In practice, the airline labor unions have increased safety through regulation changes, and education of their members (Zapf, 2014). The Air Line Pilots Association (ALPA) has initiated a bill designed to limit the duty time for the pilots and prodded the FAA to revise the Part 117 regulation: Flight and Duty Limitations and Rest Requirements: Flight Crew Members (NewMyer et al., 1992; Rudari et al., 2016). Fatigue as identified by many safety researchers can not only affect individual employee performance and safety but also general safe and smooth operations of highly complex systems such as airline operations (Chang & Wang, 2010; Patankar, 2004, 2019; Perrow, 2011; Reason, 1997; Wiegmann & Shappell, 2003).

The Aircraft Mechanics Fraternal Association (AMFA) has supported congressional members to introduce H.R. 5701 an Aviation Workforce Development Pilot Program Bill to encourage young generations to participate in aviation maintenance (Rep. Markwayne Mullin (R-OK) News Release, 2018). Aviation safety researchers agree that the education efforts supported by the airline unions could protect the individual employee, advance the safety agenda such as the education and implementation of new safety programs, and encourage professional behavior changes, efforts that can and will improve aviation safety levels (Helmreich, 1998; Patankar, 2019; Perrow, 2011; Rankin et al., 2000; Reason, 1997, 2000; Wiegmann & Shappell, 2003).

The aircraft mechanic unions within the multiple airlines entailing both low cost carriers (LCC) and network carriers have displayed the most vocal and fierce remonstration against airline maintenance outsource in the form of strikes and protests (Arnold, 2019; Helleloid et al., 2015). And maintenance labor unions often claim outsourced maintenance hurts aviation safety; overseas MRO providers are inferior compared with the work done in-house due to outsourced labor's low technical competency: the majority of the mechanics employed by the repair stations are underqualified (not having FAA A&P mechanic certificates), have limited English proficiency, and suffer an inadequacy of stringent oversight from the FAA (Ridge Global, 2018; Romano, 2019; Transport Workers Union of America, 2018).

Airline Management

Harvard Professor Michael Porter (1980, 2008) listed five forces that have shaped industry competition: threat of new entrants, bargaining power of buyers, threat of substitute products and services, bargaining power of suppliers, and rivalry among existing competitors exerted from potential entrants, customers, substitute products, suppliers, and industry rivals. The post-1978 airline industry has experienced dramatic changes including bankruptcies, new entrants, and consolidations in recent years (Callaci, 2020; Fischer et al., 2008; Goetz & Vowles, 2009; Helleloid et al., 2015). Fuel, labor, and fixed assets like aircraft make up major cost groups for the airline industry (Belobaba et al., 2016; Bourjade et al., 2017; Jorge-Calderon, 2016; Wensveen, 2011). To capture reliable and dependent income, airlines develop networks (hub-and-spoke), low cost carriers (point-to-point), and regional airlines (focusing on specific geographic areas) strategies to attract different paying passengers (Belobaba et al., 2016; Bennett & Craun, 1996; Bruce et al., 2018; Government Accountability Office, 2004; Porter, 2008). Currently, airline management generally considers that aircraft maintenance is a non-value-added activity and they are strong advocates of aircraft maintenance outsourcing in order to lower operating cost

(Bazargan, 2016; Government Accountability Office, 2004; McFadden & Worrells, 2012), and to circumvent organized strikes initiated by unions which shock the financially anemic airlines (Card, 1996; Chaison, 2007; Greer, 2009; Hirsch, 2006; Hirsch & Macpherson, 2000).

Besides taking advantage of the inexpensive labor of MRO and avoid the negative influences from unions, another issue prompts airline management to outsource airline maintenance: the airlines do not possess enough capacity to maintain all their aircraft, so instead they choose to keep in-house activity only for "critical needs" as defined by themselves (Al-kaabi et al., 2007; Bağan & Gerede, 2017). The new entrant airlines with limited MRO capacities or the airlines that exclude MRO from their business model are the airlines are the most likely to outsource maintenance work (McFadden & Worrells, 2012). Bağan and Gerede (2019) found that airlines choose third party MRO providers based on the price of the maintenance work and the duration of the time needed to finish the work.

On the other end of the spectrum, there are only a few airline-affiliated MRO providers. Delta TechOps and Lufthansa Technik are airline-MRO providers who not only serve their mother airlines, but also cater for the MRO needs of business aviation, commercial aviation, corporate aviation, public institutes, and military aviation across the globe (Denis, 2012). These name brand airlines usually share traits such as large and diverse fleet composition, extensive geographic networks, and most importantly they own a huge capacity of hangar space, equipment and maintenance labor force so that they can absorb other contracts to generate profits for the mother companies (Al-kaabi et al., 2007). Moreover, the MRO service for competing airlines is fungible, and such service also satisfies the scale economy and reputation effects (Williamson, 1985).

U.S. Government

FAA

Historically, the Federal Aviation Administration (FAA) assumed the dual responsibilities of promoting civil air commerce and regulating aviation safety (Kraus, 2008; Lu et al., 2006). However, this dual responsibility was proven to be an inefficient system as it was a conflict of interests violation for the FAA to take on both responsibilities (Carlisle, 2001; Lu et al., 2006; Nader & Smith, 1994). After having corrected the mistake by removing the responsibility of promoting civil air commerce, the FAA is currently solely responsible for the safety of civil aviation activities including the regulation of civil aviation, civil aeronautics innovations, air traffic management service for both civil and military aircraft, improvement of the National Airspace System, designing and implementing programs to reduce negative impacts on the environment due to civil aviation, and the regulation of U.S. commercial space transportation (Federal Aviation Administration, 2016a).

In short, the FAA has assumed the following functions to ensure the safety of civil aviation and suborbital commercial space operation: regulation, certification, registration, (in-flight) security, cartography, education, funding, investigation, and operation (Hamilton & Nilsson, 2015). Of these, regulation, certification, education, funding and investigation are closely related to airline aircraft maintenance. The FAA regulates commercial aviation maintenance activities, and certifies aircraft maintenance service providers, airlines, and aircraft mechanics and repairmen through Title 14 of the Code of Federal Regulations (14 CFR) Part 145-Repair Stations, 14 CFR Part 121-Air Carrier Certification, 14 CFR Part 65- Certification: Airmen Other Than Flight Crewmembers, and issues Airworthiness Directives (ADs) to correct unsafe airworthiness conditions by mandating the inspection or modification of previously certified aircraft (Hamilton & Nilsson, 2015; Hessburg, 2001). The FAA also educates the members of aviation stakeholders through advisory circulars (ACs) and seminars, and trains its own employees and related domestic and foreign government officials at the FAA Academy in the Aeronautical Center in Oklahoma City and other sites (Hamilton & Nilsson, 2015). The FAA also helps direct funds to address aviation labor force shortages and assists people who aspire to become aircraft mechanics, avionics technicians, and aerospace engineers (Dillingham, 2014). The FAA is hardly missing from the aviation mishap investigation process (Bibel, 2008; Cusick et al., 2017; Hamilton & Nilsson, 2015). At the most, airline maintenance outsourcing could get oversight from the FAA, foreign regulators (if offshored), airlines, and repair stations.

Table 2 *Multiple Oversight Roles Involved in Outsourced Maintenance*

Title	Oversight Role
FAA Certificate Management Inspector (CMO)	Assesses whether air carriers' maintenance oversight programs ensure domestic and foreign repair stations use carrier procedures when repairing aircraft and parts.
FAA Flight Standards District Office Inspector (FSDO)	Ensures that FAA-certificated domestic repair stations meet FAA standards.
FAA International Field Office Inspector (IFO)	Ensures that FAA-certificated foreign repair stations meet FAA standards.
Foreign Aviation Authority Inspector	Through agreements with Germany, France, Ireland, and Canada, certifies and oversees FAA-certificated or U.S. carrier-used aircraft repair stations in these countries (FAA has reserved the right to do random spot inspections).
Air Carrier Auditor	Conducts pre-contract award and periodic follow-up audits of repair stations.
Air Carrier On-Site Technical Representative	Provides full-time quality control at repair stations performing heavy aircraft checks to ensure they comply with the contract, FAA standards, and air carrier requirements.
Repair Station Auditor	Conducts internal and external audits to ensure repair station and its subcontractors comply with FAA and air carriers' standards

Note. Adapted from "Air Carriers' Outsourcing of Aircraft Maintenance," by Office of Inspector General, 2008, p. ii. Copyright 2008 by Author.

Undoubtedly, the FAA as a regulator, is an important layer to prevent accidents from happening via oversight of maintenance safety both inhouse and outsourced (Cusick et al., 2017; Perrow, 2011; Reason, 1997), but it often encounters difficulty such as inflexibility of bureaucracy, slow responses to technology, lack of funding, limited number of qualified aviation safety personnel, and government shutdowns (Ballesteros, 2007; Monaghan, 2011; Moore, 2001; Nader & Smith, 1994; Office of Inspector General, 2002; Partnership for Public Service, 2019; Quinlan et al., 2014).

GAO and OIG

As the watchdogs for the federal government, the U.S. Government Accountability Office (GAO) and Office of the Inspector General (OIG) closely monitor the FAA and other entities working with aviation, and they have found many deficiencies of these organizations and their programs throughout the years. The key findings on problems of airline maintenance outsourcing since the 1990s are summarized below.

The GAO (1997) found that the FAA was ill-prepared for the safety inspections of repair stations using the traditional single inspector approach. Both the FAA and the repair stations lacked safety inspection documentation and follow-ups, and the FAA oversight was more geared towards air carriers than repair stations. The GAO (1997) made the following recommendations to the FAA: (1) expansion of the locally based team to conduct inspections of large, complex, poorly recorded repair stations, (2) development of checklist and aids for the inspectors as a way to make the inspection more comprehensive and standard, (3) specifications of documents the repair stations needed in order to store records for completed inspection results and follow-up actions, (4) improvement of data collection and monitoring for use within the future Safety Performance Analysis System (SPAS), and speeding up the regulation updates on the oversight of repair stations.

The GAO (2005) reviewed the strengths of the FAA's inspection oversight for 99 non-legacy passenger airlines including the traditional National Work Program Guidelines (NPG) and the new Surveillance and Evaluation Program (SEP) based on principles of system safety to identify additional risk-based inspections. Some obstackles that hindered the effectiveness of the inspection program were identified, and the GAO (2005) recommended that the FAA develop an evaluative process for SEP and improve communications and training for inspectors in system safety and risk management. The FAA complied with all the recommendations except the evaluative process for SEP because the FAA planned to add the Surveillance and Evaluation Program (SEP) to the ATOS program by December 31, 2007, so the FAA discontinued the evaluative process (Government Accountability Office, n.d.).

The GAO (2016) found airlines choose their maintenance outsource providers primarily based on three factors: (1) service quality available at repair stations, (2) cost, and (3) the use of service contracts with the OEMs. The FAA implements generally less strict requirements for the repair stations overseas compared with their domestic equivalents in terms of certification, renewal, personnel, and drug and alcohol testing, and some of these requirements were under review and expected to be revised so that they perform at the same level as the domestic repair stations. In the fiscal year of 2015, the FAA began to deploy the newest safety oversight system, the Safety Assurance System (SAS), a risk-based, data-supported oversight system to help standardize how its inspectors identify safety risks in planning and conducting oversight, including repair of stations, airlines, and air taxi operators (Britton, 2016). The GAO (2016) found the design of the SAS fully meets three of the five principles the FAA identified as key for the safety assurance component and partially meets the other two principles, which involve data collection and management review. The GAO (2016) made the following recommendations to the FAA: (1) development and incorporation of Flight Standards on critical maintenance activities of the U.S. airlines performed by the repair stations to the SAS, and (2) development and implementations of an evaluative process that will be able to measure the effectiveness of SAS as the SMS safety assurance component. The FAA complied with the second recommendation, and left the first one open based on the reason that there is a lack of compelling safety cases supporting the recommendation; also compliance with the recommendation is useless and burdensome for the agency (Government Accountability Office, n.d.).

The OIG (2002) found the FAA was slow to implement the Air Transportation Oversight System (ATOS), an aviation safety oversight system. Air carriers did not sufficiently oversee their own maintenance systems: the FAA's failure to correct common threads impeding the FAA's ability to improve its oversight which includes collection and use of safety data, inspector training, and follow-up on previously identified safety problems.

The OIG (2003) criticized the FAA for not adequately overseeing the outsourced MRO providers despite increased outsourcing of maintenance to both foreign and domestic repair stations. The findings on seven foreign and eight domestic repair stations include the use of outdated maintenance manual, negligence of notifying the FAA of changes in the repair stations' work capabilities, and failure to segregate scrapped parts from usable parts.

The OIG (2005b) found that the air carriers have not only let the non-certificated repair facilities work on non-significant maintenance items (which is widely accepted) but also noted critical repairs which should be performed only by the certificated entities. In addition, neither the FAA nor the six air carriers in the OIG report had provided adequate oversight of the work that non-certificated facilities had performed. And, the FAA had almost no oversight on comparable non-certified facilities.

Table 3 *Key Regulatory Differences between FAA Certificated Repair Stations and Non-Certificated Facilities*

Requirement	Certificated Repair Station	Non-Certificated Facilities
FAA Inspections	Annual inspection required	No requirement
Quality Control System	Must establish and maintain a quality control system that ensures that repairs performed by the facility, or a subcontractor are in compliance with regulations	No requirement
Reporting Failures, Malfunctions, and Defects	Must report failures, malfunctions, and defects to FAA within 96 hours of discovery	No requirement
Personnel	Must have designated supervisors, inspectors, and return to service personnel	No requirement
Training Program	Required starting April 2006	No requirement
Facilities and Housing	If authorized to perform airframe repairs, must have facilities large enough to house the aircraft they are authorized to repair	No requirement

Note. Adapted from "Review of Air Carriers' Use of Non-Certificated Repair Facilities," by Office of Inspector General, 2005, p. 12. Copyright 2005 by Author.

The OIG (2007a) testified to Congress and expressed their concern that the FAA safety inspectors had not effectively used the ATOS due to lack of training, loss of information regarding where and how critical maintenance had been performed between the FAA and airlines, insufficient training of non-certified repair station employees, and the FAA's difficulty in maintaining adequate inspections due to its huge workload and financial stress. The OIG (2007b) testified to Congress and indicated the major regulatory differences between domestic and foreign repair stations as described below.

Table 4 *Key Regulatory Differences between Domestic Repair Stations and Foreign Repair Stations*

Regulatory Difference	Domestic FAA-Certificated Repair Stations	Foreign FAA-Certificated Repair Stations
Duration of FAA Certificate	Indefinite	Must be renewed every 1 to 2 years
Fees for certification	Do not pay FAA for certification	Pay FAA for certification and renewal costs
Drug and Alcohol Testing Program	Required	Not required
Certificated Mechanics	Certain personnel, such as return to service and supervisory personnel, must be FAA-certificated	Personnel are not required to be FAA-certificated (*Note: Personnel must meet certain training and qualification requirements. Mechanics may be certificated by the aviation authority where they are located.)*
Security Regulations	Repair stations on commercial airport property are subject to security requirements	Repair stations are not subject to U.S. security requirements

Note. Adapted from "Aviation Safety: FAA Oversight of Foreign Repair Stations," by Office of Inspector General, 2007, p. 6. Copyright 2007 by Author.

In the same document, the OIG also reiterated the problems identified in the previous statement: weak oversight of repair stations, non-certificated repair facilities, and an imminent shortage of qualified inspectors (Office of Inspector General, 2007b).

The OIG (2008) found that the FAA needs to be better informed regarding the following points: how much and where outsourced maintenance is performed, the FAA needs to ensure that airlines and repair stations have strong oversight systems, the FAA needs better processes for documenting inspection results, and the FAA should expedite actions to ensure the airlines better define their maintenance procedures so that they can be fully understood by the repair stations. The OIG (2009) found that the FAA lacks the data and process to identify contract maintenance providers that perform critical repairs, and the FAA over-relies on the air carriers' safety programs even with their knowledge of the faults in the programs. The OIG (2013) found that the FAA has not fully embraced a risk-based system in overseeing foreign repair stations, and the FAA's oversight of foreign and domestic repair stations lacks effective, standardized processes for identifying deficiencies and verifying that they have been addressed.

Besides the problems of the repair stations and non-certificated repair facilities across the globe, the OIG also identified similar problems within major passenger airlines and the FAA oversight over the years. Moreover, the problems are not limited to improper oversight of regulator (Office of Inspector General, 2007c). Issues include the degrading of the airline maintenance performance monitoring system—Continuing Analysis and Surveillance System (CASS), an increase in maintenance deferrals not tracked comprehensively by the FAA (Office of Inspector General, 2010), and regulators' failure to use the new oversight system, the Safety Assurance System (SAS) (Office of Inspector General, 2019).

Congress

The legislative branch of the U.S. government is the United States Congress or U.S. Congress. It is made up of two houses, the Senate, consisting of 100 Senators elected by 50 states (each state has two Senators), and the House of Representatives consisting of approximately 440 Members proportional to each state or territory's population (Sullivan, 2007). Diverse and unbounded legislative proposals can be instituted by a Member of Congress, an individual or citizen group petitioning Congress Members, State Legislatures, executive communications from the Executive branch including the U.S. President, Cabinet Members, or the head of an independent agency (Hessburg, 2001; Sullivan, 2007). The Congress initiates the introduction of proposals in one of four forms: the bill, the joint resolution, the concurrent resolution, and the simple resolution. The most common form for civil aviation-related legislation is the bill (Hamilton & Nilsson, 2015; Hessburg, 2001). A bill is the form used for most legislation, and it can be permanent or temporary, general or special, public or private.

A bill that has been agreed to in identical form by both bodies (the House of Representatives and the Senate) becomes the law of the land only after (Sullivan, 2007, p. 6):

(1) Presidential approval; or
(2) failure by the President to return it with objections to the House in which it originated within 10 days (Sundays excepted) while Congress is in session; or
(3) the overriding of a presidential veto by a two-thirds of votes in each House.

The general process of the legislative process is shown in the following diagram:

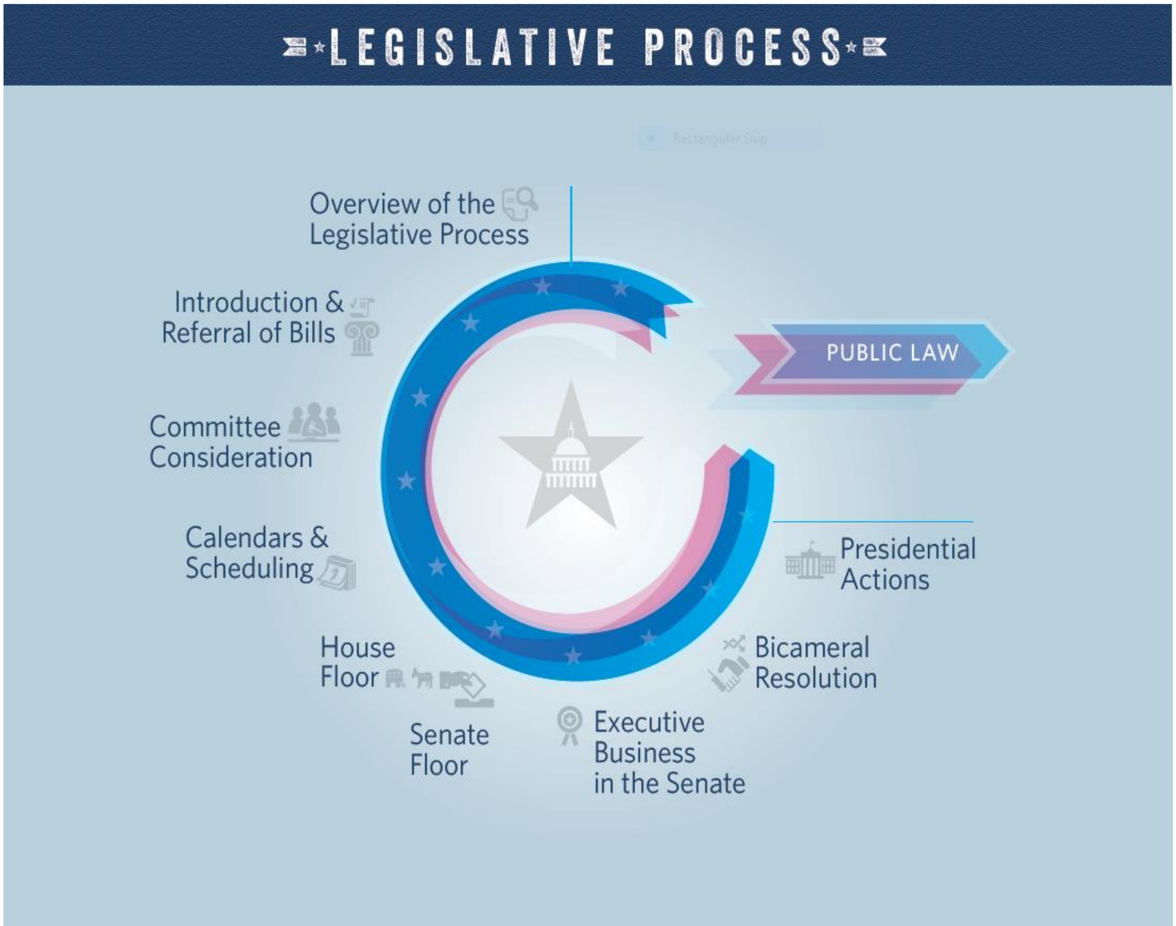

Figure 2. The Legislative Process

Note. Adapted from "Overview of the Legislative Process (Transcript)," by the United States Congress, 2021(https://www.congress.gov/content/legprocess/legislative-process-poster.pdf). In the public domain.

The airline industry makes very significant contributions to the U.S. economy. Airline operations have brought 156.1 billion dollars (2020 dollars) to the GDP, and airline annual expenditures run as high as 519.2 billion dollars (2020 dollars). In 2016, these two amounts contributed 3.6% of the U.S. GDP (Federal Aviation Administration, 2016c, 2020). At the same time, bankruptcy is an accepted business outcome in the airline industry (Belobaba et al., 2016; Fischer et al., 2008). Airlines have received funding from Congress during difficult periods such as the 2001 September 11 relief package and the 2020 Covid-19 relief funding (Hamilton & Nilsson, 2015; Rucinski & Shepardson, 2021; Wensveen, 2011).

The economic and safety status of airlines can directly affect the traveling interests of constituents and public image of elected politicians and government. Airline labor makes up a good portion of the local electorate in some hub cities (Fischer et al., 2008; Nader & Smith, 1994). Debate over whether to allow airline maintenance outsourcing is beyond the issues of technology and economics, it is a POLITICAL problem. Discussions regarding concerns over the FAA's lack of safety oversight and the irresponsibility of airline maintenance outsourcing have frequently occurred in Congressional hearings throughout the years (*A Review of Aviation Safety in the United States*, 2012; *The State of Aviation Safety: Hearing before the Subcommittee on Aviation of the Committee on Transportation and Infrastructure House of Representatives 115th Congress 2nd Session*, 2018; *The Federal Aviation Administration's Oversight of Outsourced Air Carrier Maintenance*, 2007; Romano, 2019). A detailed Congress report indicated that no concrete evidence showed that airline maintenance outsourcing did affect aviation safety, but specific areas related to FAA oversight and the incapability of foreign repair stations were found legitimate, and the U.S had maintained a positive trade balance in aircraft MRO at the time (Tang & Elias, 2012).

The recent 116th Congress (2019-2020) Democratic Party in the House of Representatives has made efforts to curb airline maintenance outsourcing.

The first proposal was from U.S. House Representative John Garamendi (Democratic Party – California). He (2019) introduced the "Aircraft Maintenance Outsourcing Disclosure Act of 2019" to require the Federal Aviation Administration to mandate that an air carrier providing scheduled passenger air transportation: (1) disclose to the public the date and location of the most recent heavy maintenance for specific flights, and (2) provide a similar disclosure for its entire fleet.

The second proposal was from U.S. House Representative Peter DeFazio (Democratic Party – Oregon), he (2019) introduced "Safe Aircraft Maintenance Standards Act" to the House floor. And this bill requires that all overseas repair stations have at least one unannounced inspection each year, all airlines must submit monthly reports of maintenance, preventive maintenance, or alternations of an aircraft to the FAA. It also sets forth minimum qualifications for maintenance personnel working on U.S. registered aircraft at foreign repair stations and establishes a moratorium on FAA certification of new foreign aircraft repair stations if certain regulations are not implemented within one year (DeFazio, 2020).

Both bills have gained support from the airline mechanic labor unions including Transport Workers Union International, the Aircraft Mechanics Fraternal Association, and the International Brotherhood of Teamsters. The air transport industry and unions have made significant political donations to their campaigns the amounts of which, classified by industry, are listed in the tables below (Center for Responsive Politics, 2020b, 2020a).

Table 5 *Congressman Peter DeFazio Political Donation Source Classified by Industry, 2019-2020*

Industry	Total	Individuals	PACs
Retired	$317,189	$317,189	$0
Leadership PACs	$302,007	$4,506	$297,501
Air Transport	$273,838	$66,838	$207,000
Democratic/Liberal	$250,234	$242,734	$7,500
Lawyers/Law Firms	$220,452	$146,702	$73,750

Note. Adapted from "Rep. Peter DeFazio - Campaign Finance Summary," by Center for Responsive Politics (OpenSecrets), 12/31/2020, Copyright 2020 by Author.

Table 6 *Congressman John Garamendi Political Donation Source Classified by Industry, 2019-2020*

Industry	Total	Individuals	PACs
Transportation Unions	$100,500	$0	$100,500
Real Estate	$61,020	$46,520	$14,500
Building Trade Unions	$48,200	$0	$48,200
Public Sector Unions	$46,000	$0	$46,000
Sea Transport	$44,500	$0	$44,500

Note. Adapted from "Rep. John Garamendi- Campaign Finance Summary," by Center for Responsive Politics (OpenSecrets), 12/31/2020, Copyright 2020 by Author.

Lobbyists

Outside unions, airlines, MRO providers, and the U.S. government agencies, there are active lobbyists in Congress regarding the issue of whether or not to restrict airline maintenance outsourcing.

ARSA

Founded in 1984, the Aeronautical Repair Station Association (ARSA) is an international trade association representing certificated aviation maintenance and alteration facilities before the U.S. Congress, the FAA, the EASA, and other civil aviation regulators (Aeronautical Repair

Station Association, n.d.). The Managing Director & General Counsel of the ARSA, Mr. Filler (2007) stated to the Congress that foreign repair stations are an essential part of aviation business, and the FAA certified repair stations located overseas must follow the same or equivalent safety standards as their domestic counterparts so that the quality of maintenance is guaranteed by the industry partners instead of regulators alone. ARSA Executive Director Sarah MacLeod in the panel discussion at Aircraft Maintenance Outsourcing Summit voiced ARSA's opposition to the legislation proposal. It imposes many "impractical" requirements such as mandating a 2:1 ratio of certificated mechanics to non-certificated personnel in airframe repair facilities and the online publication of at least one year's maintenance history for each aircraft (including percentages of airline vs. outsourced maintenance personnel and mechanics vs. non-certificated technicians). According to the ARSA, " the legislation may not pass the laugh test for those working in the maintenance industry, but that doesn't mean it won't gain traction on Capitol Hill" (Aeronautical Repair Station Association, 2019).

Passengers/Consumers Advocates

Passengers have been enjoying the benefits of the deregulation of air travel since 1978 and its consequent competitions across the globe (Belobaba et al., 2016). One major positive ramification of the competitions among the airlines after deregulation is the suppression of air travel costs and the lowering the price of air travel (Goetz & Vowles, 2009). The U.S. Department of Transportation Bureau of Transportation Statistics (2020) calculated that the average air fare adjusted for inflation dropped from $490 in 1995 to $355 in 2019. To keep the operating and other costs low, more and more airlines are outsourcing their maintenance to third parties so that they are able to offer lower air ticket prices to entice passengers who are usually price-sensitive customers (Brons et al., 2002; Czepiel, 2003; McFadden & Worrells, 2012)

There are safety concerns, however, from the passengers who fly on the aircraft overhauled by non-airline entities, especially those repairs done overseas because these aircraft may encounter more uncertainties ranging from maintenance delays on the ground to catastrophic disasters (Business Travel Coalition, 2008; Steele, 2015). However, Borenstein and Zimmerman (1988) found that fatal air accidents have exerted a negative, but not statistically significant, effect on air travel demand since the 1978 deregulation. Generally speaking, paying passengers tend to prioritize price over other factors (Belobaba et al., 2016; Kim et al., 2005; Wensveen, 2011; Yu, 2008).

In U.S. politics, airline passenger advocacy groups are strong opponents to airline maintenance outsourcing. One of these high profile groups is the Airline Consumer Action Project (ACAP) founded in 1971 by Ralph Nader who was a political activist and a four-time candidate (1996, 2000, 2004, and 2008) for the U.S. presidency (Tikkanen, 2021). He founded ACAP to "promote airline safety and the rights of the traveling public before federal agencies of the executive branch and Congress" (Nader & Smith, 1994, p. 337). APAC has in the past exposed the unethical practice of the underreporting of near midair collisions, and it brought back the correct reporting practice (aiReform, 2013). Ralph Nader has been a strong vocal critic of airline maintenance outsourcing and the FAA's futile efforts to regulate aviation safety, in which he described, "…When they [the FAA] do take regulatory action to protect public safety, like a teenager that doesn't complete his homework, the agency fails to finish the job" (Nader & Smith, 1994, p. 71). Ralph Nader is a frequent spokesperson against airline maintenance outsourcing, and his motivations are generally in alignment with the unions' claims: outsourced/offshored maintenance is inherently unsafe, and there is no way for regulators and airlines to oversee it (*Aircraft Maintenance Outsourcing Summit*, 2019; Nader, 2015; Nader & Smith, 1994; PR Newswire, 2019).

PASS

Founded in 1977, the organization of Professional Aviation Safety Specialists (PASS) is a union consisting of more than 11,000 employees of the Federal Aviation Administration (FAA) and Department of Defense (DoD) (Professional Aviation Safety Specialists, 2019). Among their members are FAA safety inspectors, and they are in line with the airline labor unions to oppose airline maintenance outsourcing, especially airline maintenance offshoring. PASS cosponsored the legislation proposed by the Democrat Congress members (DeFazio, 2019; Garamendi, 2019). PASS has offered legitimate reasons to support their agenda before both the Senate and House committees.

In 2007 the Senate Committee on Commerce, Science, and Transportation-Subcommittee on Aviation Operations and Security hearing, PASS expressed the following concerns with airline maintenance outsource. The FAA lacks a viable staffing model to maintain adequate inspectors to oversee outsourced maintenance work as confirmed by (*Staffing Standards for Aviation Safety Inspectors*, 2006). The PASS president mentioned in the hearing that one avionics inspector had to cover 165 certificated repair stations in England and Scotland due to his coworker's medical leave (*The Oversight of Foreign Aviation Repair Stations*, 2007). Funding constraints have limited international travel to conduct inspections at remote foreign repair stations as confirmed by the DOT IG report (Office of Inspector General, 2005a), and these constraints impede the CMO and IFO inspectors to do follow-up checks on the issues discovered in the earlier inspections. In addition, there are concerns with governmental policies (*The Oversight of Foreign Aviation Repair Stations*, 2007). The regulatory differences have enabled foreign repair stations to be less scrutinized regarding no drug alcohol policies, and no unannounced inspections on foreign soil (Office of Inspector General, 2007b) To circumvent the inspector staffing and funding problems, the FAA has delegated its inspection work to the foreign civil aviation regulators through the Bilateral Aviation Safety Agreement (BASA), and allows airline to use non-certificated repair stations which the FAA does not need to inspect by law (*The Oversight of Foreign Aviation Repair Stations*, 2007; Office of Inspector General, 2005b).

In 2019 the House Committee on Transportation and Infrastructure-Subcommittee on Aviation hearing, PASS addressed the longest government shutdown, and also the most costly to the U.S. economy in U.S. history$8 billion (2019 value) as estimated by the Congressional Budget Office (Edelberg, 2019). In the statement, the PASS president Michael Perrone expressed the following concerns with airline maintenance outsourcing: its members were furloughed for 35 days without a paycheck, aviation safety inspectors could not inspect both foreign repair stations, and domestic airlines for that period, and the shutdown exacerbated the difficulty of hiring journeymen inspectors and retaining experienced inspectors to cope with the backlog of the workload (*Putting U.S. Aviation at Risk: The Impact of the Shutdown*, 2019).

Aviation Safety

The Concept of Aviation Safety

A safe and secure air transportation system is important for a country's national security and economic success (Ballesteros, 2007; Hansen et al., 2008). However, safety and security are often interchangeable and confused in different languages including English. In Chinese, there are words for safety and security: “安全” and “安防” respectively; in German, “Sicherheit” can mean both safety and security. In daily usage, the word “safety” often covers the meaning of “security”. As a matter of fact, the difference between safety and security lies in intentionality. Safety can be defined as “measures taken against the threat of an accident,” and security as “protection from threats motivated by hostility or malice” (Wells, 2001, pp. 302–303). Since the majority of this research will address aviation activities regulated by the FAA, and its definition of safety has been adopted: “The state in which the risk of harm to persons or property damage is acceptable” (Federal Aviation Administration, 2017, p. A-2).

Evolution of Aviation Safety

There have been four major approaches toward aviation safety between the1900s and the 2010s: technical, human factors, organizational, and system safety (International Civil Aviation Organization, 2018). During the technical era (early 1900s and late 1960s), the industry adopted a reactive approach, trying to identify the technical causes of past events such as aviation accidents and incidents (Cusick et al., 2017; Liou et al., 2008; Stolzer, 2016; Wood, 2003). In this era, most of the accidents were due to technical failures (Lederer, 1953; Reason, 1997; Wiegmann & Shappell, 2003). In response, aviation pioneers put enormous efforts into coming up with ingenious designs to overcome technical challenges and expand the margins of safety and efficiencies (Grant, 2002; Hansen et al., 2008). These efforts included rounding square windows after discovering that the midair breakups of De Havilland Comets were caused by the stress concentration on square window corners, to the development of propulsion technology which lowered the chance that an average flyer would encounter an inflight engine shutdown once every 17 years (Connors, 2000; Federal Aviation Administration, 2018). In the cockpit, the pilots become managers who supervise and monitor the all the complex system performance during the normal operation for the sake of safe and efficient operation, and they only exert more direct control; employing their traditional psychomotor skills in the event of system stoppage and malfunction (Edwards, 1977; Perrow, 2011).

With the expansive development of science and technology as time has progressed, aviation safety research and development entered an era of human factors (International Civil Aviation Organization, 2018; Oster et al., 2013). In this era (early 1970s and late 1990s), more and more accidents/incidents were found to be related to human factors, that is to how individuals and crews work together in unique environments (Helmreich, 1998; Patankar, 2004; Wiegmann & Shappell, 2003). The industry and academia started to ask not how much work a person could do safely, but how little (Perrow, 2011; Wiener, 1977)? In response to this question, the industry has come up with specific programs such as the Crew Resource Program and the Maintenance Resource Program to tackle issues related to human factors both in the air and on the ground (Hawkins, 1993; Helmreich, 1998; Lu, 2003; Patankar, 2004). In retrospect, the first era concentrated on past events and equipment from the angle of technology, and the second era concentrated on operating status and the realm of human factors (Lercel, 2013).

With improved methods of data collection, the industry began to address aviation safety from a systemic perspective and began considering organizational as well as human and technical factors(Bowen & Lu, 2000; International Civil Aviation Organization, 2018). Now the identification of problems and safety data analysis of daily operations has become part of the safety manager's regular work (Ballesteros, 2007). With further deep analysis, researchers have identified a new dimension involving accidents/incidents stemming from organizational decisions and attitude; it is referred to as the organizational factor (Hawkins, 1993; Perrow, 2011; Reason, 1997, 2016; Wiegmann & Shappell, 2003). The epitome product of the organizational factor era (mid 1990s and early 2000s) is the development and current implementation of Safety Management System (SMS) (International Civil Aviation Organization, 2018).

Total aviation system approach sees the entire aviation industry as a system, in which all service providers, and their systems for the management of safety, are considered as sub-systems (International Civil Aviation Organization, 2018). "It is a subdiscipline of systems engineering that applies scientific, engineering, and management principles to ensure adequate safety, the timely identification of hazard risk, and initiation of actions to prevent or control those hazards throughout the life cycle and within the constraints of operational effectiveness, time, and cost" (Vincoli, 2014, p. 218). And system safety take seriatim (Vincoli, 2014, pp. 20–21):

1. Design for minimal risk
2. Incorporate safety devices
3. Provide warning devices
4. Develop procedures and training
5. Acceptance of residual/remaining risk

This approach has been adopted so that all the service providers and aviation stakeholders can take a proactive approach to safety instead of a reactive approach toward aviation safety (Batuwangala et al., 2018). Entering the 21st century, many States and service providers have embraced the safety approaches of the past and evolved to a higher level of safety maturity. They have begun implementing State Safety Programme (SSP) or safety management system (SMS) and are reaping the safety benefits.

Recently, more and more people have come to realize the effectiveness of taking a predictive approach to analyze aviation, that is to analyze the system process and environment to identify potential/ future problems (Federal Aviation Administration, 2016b).

Safety Management System

Safety management system is an evolutionary offshoot of system safety concepts developed for military applications and quality management systems (QMS) for business and process optimization, and is practiced by the occupational health and safety management system, nuclear, and various other industries (Lercel, 2013; Li & Guldenmund, 2018; Stolzer, 2016).

Globally, the SMS for aviation was established and promoted as a useful tool to address aviation safety when the International Civil Aviation Organization (ICAO) formally adopted the procedure- ICAO Annex 19 (2013) to provide Standards and Recommend Practices (SARPs) to facilitate the development and implementation of State safety programs and SMS (Gnehm, 2013). Over time, the major civil aviation authorities around the world are integrating the safety management system (SMS) into their regulatory frameworks and mandating their air service providers to implement the SMS in a timely manner (Leib, 2014). The fourth edition of the Safety Management Manual (SMM) was published in 2018. Compared with the last edition, the latest edition is able to address the changes introduced by Annex 19, amendment 1 adopted on 2 March 2016, and reflects the knowledge and experience gained since the previous 2013 revision.

In this research, the FAA definition of SMS has been adopted, and is listed in the definition section. The FAA SMS is built around four components: safety policy, safety risk management (SRM), safety assurance (SA), and safety promotion. The safety policy is where the organizations to set objectives, assign responsibilities, and set rules. The SRM component supplies a decision-making process for identifying hazards and mitigating risk based on a thorough understanding of the organizational system and the environment in which it operates. SA serves as quality assurance in the manufacturing setting, in which the organizations monitor and measure the safety performance of operational processes and continuously improve the level of safety performance. The final component, safety promotion focuses on training and communication so that organizations understand their safety responsibilities, the organization's safety policies and expectations, their reporting procedures, and have a familiarity with risk controls. As for application of the SMS to airline aircraft maintenance, the FAA has only required the Part 121 air carriers to implement the SMS and has not mandated repair stations or any other MRO providers to implement SMS (Federal Aviation Administration, 2015; Lercel, 2013). Lercel (2013) found that the FAA had persuaded the repair station to accept SMS through traditional policy implementation approach, and repair station refused to do it based on the economic reason , and he proposed a scalable implementation of SMS- "*the Application-based Model for SMS compliance by Part 145 Repair Stations*", and repair stations who work on transport aircraft should serve a basis for SMS compliance.

Summary

This chapter introduced the concept, reasons, scope of airline maintenance outsourcing, and outsourced maintenance safety problems. It also reviewed two fatal accidents involving airline maintenance outsource factors. It also offered several key stakeholders' viewpoints on airline maintenance outsource issues. This chapter concluded with a discussion about aviation safety. The next chapter discusses this study's methodology.

CHAPTER 3. METHODOLOGY

Research Design

This study used a mixed methods research design, which is a procedure for collecting, analyzing and "mixing" both quantitative and qualitative data at a certain stage of the research process within a single study, to solve a research problem (Creswell, 2018; Tashakkori & Creswell, 2007).

"Quantitative research often refers to approaches to empirical inquiry that collect, analyze, and display data in numerical rather than narrative form" (Given, 2008, p. 175). Quantitative research designs include, but are not limited to, descriptive research designs, correlational research designs, pre-experimental designs, quasi-experimental designs (also known as causal-comparative designs), true experimental designs (Salkind, 2012; Sekaran & Bougie, 2016).

"Qualitative research examines phenomena within the cultural and social context in which it takes place" (Salkind, 2012, p. 397). Merriam (2016) found the following elements in qualitative research: a focus on understanding the meaning of experience, the researcher as the primary instrument in data collection and analysis, an inductive process, and a rich description characterizing the end product. Merriam also discusses common types of qualitative researches throughout his book: basic qualitative research, phenomenology, grounded theory, ethnography, narrative analysis, qualitative case study, as well as other types of research including action research, critical research, arts-based research, and mixed methods qualitative research (Merriam, 2016).

Mixed methods research has been proven to be a useful methodology to analyze complex issues in aviation safety research (Mabotja et al., 2019; Walala, 2016). It can be applied to the research problem addressed in this thesis as well because it allows the researchers to mix, merge, connect, and/or embed both qualitative and quantitative data in different orders and scales in order to obtain a more complete understanding of the research problems (Tashakkori & Creswell, 2007). In line with the mixed methods approach, the researcher approached the research problem from the following worldviews in the research (Creswell, 2018):

Ontology: the researcher expected to encounter multiple realities to the research questions (contradictory or sharply different answers to the same set research questions.

Epistemology: The researcher adopted a practical way to collect data by "what works" to address research questions).

Axiology: The researcher expected to integrate multiple stances (inclusion both biased and unbiased perspectives) in the conclusion.

Rhetoric: The researcher used a formal style (the third person: he, she, it, or they).

Based on the order of phases of the research, the explanatory sequential mixed methods approach (QUAN->qual) was applied, in which the quantitative research preceded the qualitative research and the emphasis of the research was placed on the quantitative part (Creswell, 2018; Given, 2008). Firstly, the quantitative research part was built on Monaghan's research with over ten more years of data and more independent and dependent variable relationships (Monaghan, 2011). Secondly, the qualitative research part involved interviews with industry practitioners and stakeholders to gain firsthand experience of the research questions. Their answers were adopted to interpret the quantitative research results (Creswell, 2018; Ivankova et al., 2006). The rationale behind this research design is that a quantitative research data analysis gives a general understanding of the research problem, and sequential qualitative data and data analysis help refine and explain the statistical results by seeking feedback from the subjects (Creswell, 2018; Ivankova et al., 2006; Rossman & Wilson, 1985).

A simplified flow chart of the current research model is provided below.

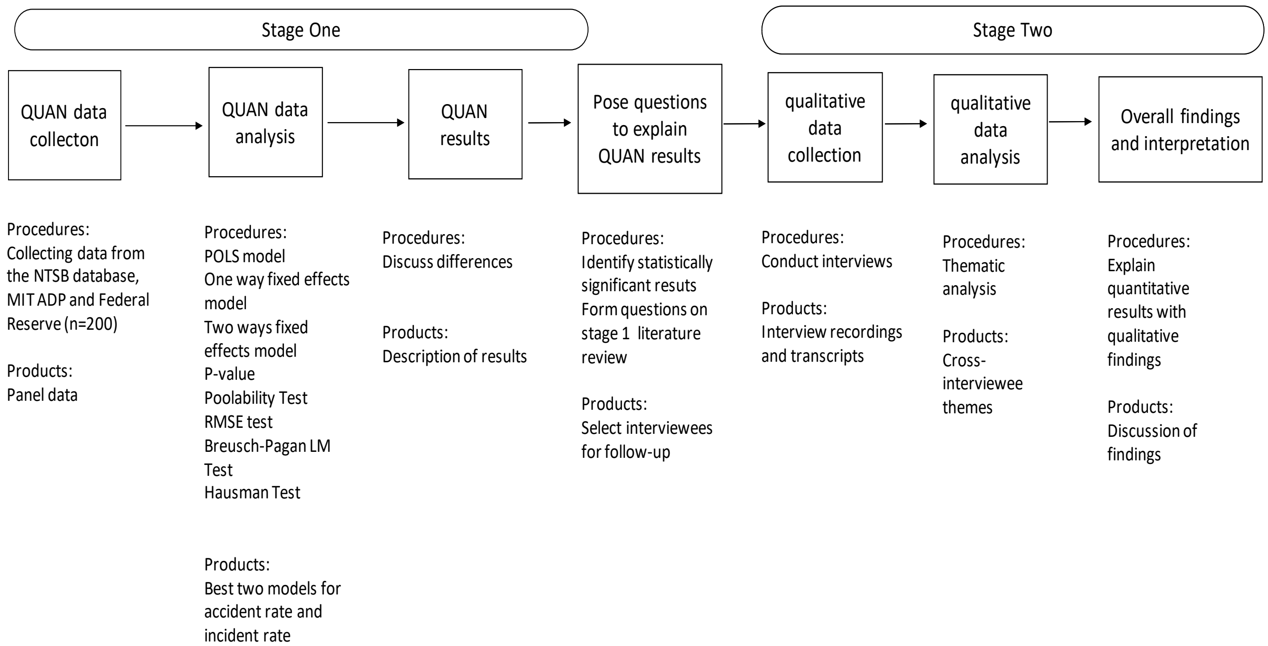

Figure 3. Explanatory Sequential Mixed Methods Research

First Stage: Quantitative Research

The first stage of the research involved a quantitative study using panel data analysis to explore the relationships between two dependent variables: airlines' safety performance metrics and independent variables identified in the literature review.

Dependent Variables

Aviation Safety Measurement

All the major aviation organizations agree the need to establish metrics to measure and quantify safety to ensure safety (European Union Aviation Safety Agency, 2019; Federal Aviation Administration, 2017; International Civil Aviation Organization, 2019). Three aspects were considered for the safety measurement: accidents, incidents and operational problems (Kalemba & Campa-Planas, 2019). The first two could be classified with a safety outcome metric, while the latter one could be classified with a safety process metric (Karanikas, Kaspers, Boer, et al., 2016; Karanikas, Kaspers, Roelen, et al., 2016). Traditionally, the NTSB and FAA have used accidents per million departures or accidents per million flight hours for gauging the aviation safety of the whole industry, however the practice fails to take the differences in equipment, mission, or environment into account (Barnett & Wang, 2000; Wood, 2003). It is a common practice for aviation safety researchers to use the number of unsafe events (fatalities, accidents, incidents and hull losses) divided by the number of flight hours or the number of flights (Barnett, 2007; Barnett & Wang, 2000; Flannery, 2001; Oster et al., 2013).

AcciRate and InciRate

In this research, the researcher used the accident rate (AcciRate-annual count of accidents per total aircraft block hours of a specific airline in a given year) and incident rate (InciRate-annual count of incidents per total aircraft block hours of a specific airline in a given year) as safety performance metrics—dependent variables because these data are publicly accessible and easy to compare across different airlines and time. The numerators of the unsafe events consist of aviation accidents and aviation incidents as defined by the NTSB. The NTSB lists all the aircraft accidents, and some incidents, under its jurisdictions. Thus, the researcher could not form a comprehensive view of the data related to the incidents, but the incomplete data could still serve as a reference to some degree. Heinrich (1950) proposed the famous iceberg theory numerical ratio:1-29-300 in regards to the counts of accidents with major injuries, accidents with minor injuries, and accidents with no injuries. In addition, common contributing factors such as the independent variables chosen in this research to model accident rates also should be able to explain the pattern of the incident rates across the airlines and time (Nazeri, 2007; Rose, 1990). The block hours were chosen as the denominator of the unsafe event rate. This choice was made because the event rate matches the time span of the accident or incident. Several unsafe events happened on the ground because of the earlier NTSB definition of accident/incident which specifies that the event takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked.

Independent Variables

Omx and MtA

The first two independent variables, Percent of maintenance expenses outsourced (Omx) and Inhouse maintenance labor to aircraft ratio (MtA) were chosen to test whether the amount of airline maintenance from the perspective of monetary value and labor to equipment ratio could affect aviation safety. In the previous discussion, some interested groups claimed that the percentage of maintenance outsourced, quantity of aircraft maintenance labor, and the expense of aircraft maintenance labor might affect aviation safety (Czepiel, 2003; Ridge Global, 2018; Transport Workers Union of America, 2018). It is worthwhile to examine whether airline maintenance outsourcing hurts aviation safety.

MxWage

The third independent variable was real average annual wages and salaries-inhouse maintenance personnel (MxWage). The relationship between organization performance (mainly financial performance) and its employee's income is recognized by many famous economists (Abel et al., 2016; Hamermesh, 2011; N. G. Mankiw, 2001; Porter, 1980; Smith, 1776/2007). They all agreed that employers pay high salaries and wages to retain and recruit productive, efficient employees with any desirable characteristics so that their business entities can maintain a positive profit margin and keep an edge over their competitors. A higher wage leads to increased labor productivity according to the efficiency wage theory as discussed in the following paragraph.

Shapiro and Stiglitz (1984) showed that workers would avoid shirking with wages significantly above market equilibrium wage, and save the firm from monitoring (supervision) costs. Rebitzer (1995) confirmed high levels of supervision are indeed associated with lower wage levels using the data of contract maintenance workers in the petrochemical industry. A complex and tightly coupled industry such as the commercial aircraft maintenance industry shows the opposite, that a direct benefit of higher wages is enhanced safety performance. Akerlof (1982) used a standard sociological model to show that if the employer pays a higher wage than the opportunity cost of leaving their current job, the workers will work harder and show stronger loyalty to the company.

In the airline industry, this rule is a bit complicated. Parast and Fini (2010) used a stepwise regression to explore the effect of productivity and quality on profitability in the U.S. airline industry based on longitudinal data from 1989 to 2008. They found that salary has a positive impact on airline profitability, while maintenance cost (including maintenance labor cost) has a negative impact on airline profitability, and the safety of an airline is a necessary condition for a profitable airline (Ballesteros, 2007; Bowen et al., 2003; Cusick et al., 2017). The specialized training and skill sets developed through work experience have enabled airline mechanics to maintain an earnings advantage compared with full-time non-airline-industry mechanics (Hirsch & Macpherson, 2000). The smooth operation of an airline is dependent on an efficient skilled team of aircraft mechanics (Bazargan, 2016; McFadden & Worrells, 2012; Rhoades et al., 2005). Captain Depete (2019), as noted in a Congressional hearing, “Skilled labor is not cheap, cheap labor is not skilled.” In this research, the researcher wanted to explore whether the wages of airline maintenance labor can affect aviation safety which as earlier stated is a necessary factor for airline profitability.

Profitability

The fourth independent variable was airline profitability. The main concern regarding the parasitic relationship between airline profitability and aviation safety is built on the logic that intensive competition since the 1978 deregulation among the airlines forces the airlines to adopt corner-cutting strategies such as smaller safety budgets, hiring less experienced mechanics, and other shortsighted policies that put the preservation of profit margins ahead of, and hence endanger, aviation safety (Quinlan et al., 2013; Rose, 1992). Historic data analysis showed mixed effects of airline profitability on aviation safety. The Rose (1990) study based on the data from 35 large scheduled passenger U.S. airlines over the 1957 to 1986 period, estimates the impact of several financial indicators including: operating margins, interest coverage, working capital, as well as current safety performance indicator ratios including accident rate-ratio of total accidents/incidents and system departures in the thousands, she found an inverse correlation between airline profitability and accident and incident rate particularly for small airlines, and Rose found that a 9.92% increase in the operating margin of individual carriers results in a 5% reduction in total accident rate. Adrangi et al. (1997) surveyed the U.S. airlines between 1938 and 1994, used the ratio of operating profits (OPF) and net operating profits (NOPF) to revenues to denote airline profitability, they chose fatalities per million revenue miles (FAPM) and fatalities per hundred thousand departures (FAPD) as safety measurements to which they applied a series of test to seek correlation, co-movement, and causality between the two measures described above. They concluded that deregulation has increased the financial risks for the airlines, but there is weak correlation between airline profitability and aviation safety. Noronha and Singal (2004) used bond ratings as a proxy for airline profitability to capture the long run effect of airline financial performance of the major U.S. airlines between January 1983 and December 1998. They found that the airlines with stronger bond ratings are safer than the financially weak ones, counting all mishaps (accidents and incidents) for a specific airline in a specific year. Based on the data of the U.S. airlines between 1980 and 2002, Raghavan and Rhoades (2005) found an inverse relationship between profitability and airline safety, especially for the smaller regional air carriers. Their methodology was based on Rose's study (1990). Kalemba and Campa-Planas (2019) found that safety exerts a non-significant effect on the profitability of the airlines, whereas it exerts a significant effect on the volume of revenue from passengers using major world airlines.

RtC

The fifth and last independent variable was Real GDP per capita (RtC). RtC is a good indicator for capturing the macroeconomy, and it has been widely used by the United Nations (1994) to measure levels of human development in countries and regions across the globe. In this research, it serves as a good proxy variable for the income level of the average U.S. passenger for each year (Abel et al., 2016; Wooldridge, 2013). Safety and economy are quite often discussed at the microeconomic level as indicated above. It is commonly agreed that the more developed an economy and civilization, the safer it is, because the people in developed civilizations care more about their welfare including safety and security, and they are able to allocate more resources to improve safety level (Huntington, 2003; Perrow, 2011; Reason, 1997, 2016; Smith, 1776/2007). As Adam Smith commented, " No society can surely be flourishing and happy, of which the far greater part of the members are poor and miserable" (Smith, 1776/2007, p. 96). However, the occupational accident rate increased during times of economic expansion (higher Real GDP per capita, and lower unemployment rate) in Poland (Łyszczarz & Nojszewska, 2018).For aviation, on the contrary, Spence et al. (2015) found that as GDP increases, aviation fatalities per 10,000 departures decrease. So, it made sense for the current study to include a variable denoting the status of the macroeconomy and test whether this variable correlates with the airline safety.

Data Handling

In the proposed correlation research, a small amount of data may be recorded incorrectly or missed from the database which may jeopardize the accuracy of the correlational research results. For example, one independent variable in the MIT database, Percent of maintenance expenses outsourced (Omx) reported by some airlines is inaccurate. Some of them are over 100%, but in theory Omx could only range between 0 and 100%.

In some years, certain variables for the airlines were missing, but these were less than 5% of the dataset. To solve the problem of the missing value, the researcher plans to impute the missing value with mean values (Jakobsen et al., 2017).

Consequently, the researcher included the following dependent variables and independent variables in Table 8 and Table 9. Table 7 allows the reader to clarify some incongruencies involving the dependent variable and the independent variables.

Table 7 *Variables Contributing to the Dependent Variables and Independent Variables*

Variable	Explanation	Source
Year	The ordinal variables ranging from 1995 to 2019	N/A.
Airline	Airline Names.	N/A.
AcciCt	The count of accidents for a specific airline in a given year.	NTSB Aviation Accident Database & Synopses.
InciCt	The count of incidents for a specific airline in a given year.	NTSB Aviation Accident Database & Synopses.
TABH	Total Aircraft Block Hours - ALL AIRCRAFT.	U.S. DOT Form 41, schedule T2.
Revenue (BN)	System Total Operating Revenue count in billion U.S. dollar.	U.S. DOT Form 41 via BTS, Schedule P12
Expense (BN)	System Total Operating Expense count in billion U.S. dollar.	U.S. DOT Form 41 via BTS, Schedule P6.
Profitability0	(Revenue-Expense)/Expense in percentage.	N/A.
InflationRate	Compounded Annual Rate of Change, Annual, Seasonally Adjusted.	U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers.
MxWage0	Average annual wages and salaries - inhouse maintenance personnel	U.S. DOT Form 41 via BTS, Schedule P6 & P10.
MxCount	Total In-House Maintenance Employee Equivalents	U.S. DOT Form 41 via BTS, Schedule P10.
TOF	Total Operating Fleet = Aircraft Days Assigned/Days in Year. Represents average fleet count over the course of the entire year.	US DOT Form 41 via BTS, schedule T2.
MtA0	MxCount/TOF	N/A.
GDPtC	GDP per capita units: Dollars, Seasonally Adjusted Annual Rate, Frequency: Annual, Average	U.S. Bureau of Economic Analysis.

Table 8 *Dependent Variables*

Variable	Explanation	Source
AcciRate	Accident Rate is AcciCt divided by TABH.	N/A
InciRate	Incident Rate is InciCt divided by TABH.	N/A

Table 9 *Independent Variables*

Variable	Explanation	Source
Omx	Percent of maintenance expenses outsourced.	U.S. DOT Form 41 via BTS, Schedule P6 & P52.
MtA	Round up of MtA0.	N/A.
MxWage	Average annual wages and salaries - inhouse maintenance personnel adjusted for inflation: MxWage=MxWage0*(1-InflationRate)	N/A.
Profitability	Airline profitability adjusted for inflation: Profitability=Profitability0-InflationRate	N/A.
RtC	Real GDP per Capita: RtC=GtC*(1-InflationRate)	N/A.

Population and Sample of the Quantitative Research

The population of the quantitative research included all the defunct and operating major mainline U.S. domestic passenger airlines between 1995 and 2019. They were comprised of the following fifteen airlines: AirTran Airways, Alaska Airlines, Allegiant Air, America West Airlines, American Airlines, Continental Airlines, Delta Air Lines, Frontier Airlines, Hawaiian Airlines, JetBlue Airways, Northwest Airlines, Southwest Airlines, Spirit Airlines, United Airlines, and US Airways.

The sample of the quantitative research consisted of the construction set of eight continuously operating airlines between 1995 and 2019 (Weisberg, 2014; Wooldridge, 2013). A panel data set entails n entities or subjects, each of which includes T observations measured at 1 through t time period, if total number of observations is not equal to n times T, that is an unbalanced panel data (Park, 2011). The sample was chosen based on the fact that it constituted a balanced panel which facilitate the easiness of the computation (Wooldridge, 2013). The airlines in the sample are Alaska Airlines, American Airlines, Delta Air Lines, Frontier Airlines, Hawaiian Airlines, Southwest Airlines, Spirit Airlines, and United Airlines. The sample size is 200: a product of eight airlines and 25 years of observations (1995-2019).

Ethical Assurance

The first stage research was exempt from review by the institutional review board (IRB) due to the publicly available data set. All the data in this stage of research came from the NTSB database, the MIT ADP, Federal Reserve are accessible to the public.

Assumptions for the Quantitative Research

To conduct this research, the researcher asserted the following assumptions:

1) The NTSB aviation accident/incident reports are accurate.
2) The inhouse maintenance labor hour for each airline is the same across the time.
3) Panel data assumptions are detailed in the following text.

The first stage of this research consisted of a panel data analysis. This data collected in the form of panel data consisted of a time series (between 1995 and 2019) for each cross-sectional member (eight airlines) in the data set (Wooldridge, 2013). “Panel data may have an individual (group) effect, time effect, or both, which are analyzed by fixed effects (FE) and/or random effects (RE) models” (Park, 2011, p. 2).

The researcher started with a simplified ordinary least squares (OLS) model:

$$y_{it} = \alpha + X'_{it} * \beta + u_{it} \qquad \text{(Eq. 1)}$$

In the above equation,α is scalar, β indicates K times i vector, X_{it} means i th airline at t th year on K independent variables, u_{it} is the error term.

OLS is built on the following five assumptions, also known as Gauss-Markov assumptions (Wooldridge, 2013).

1. Linearity says that the dependent variable is formulated as a linear function of a set of independent variables and the error (disturbance) terms.

$$y = \beta_0 + \beta_1 * x_{i1} + \cdots + \beta_k * x_{ik} + u_i \qquad \text{(Eq. 2)}$$

2. There are a random sample of n observations.

$$\{(x_{i1}, x_{i2}, \ldots, x_{ik}, y_i): i = 1 \ldots \ldots n\} \qquad \text{(Eq. 3)}$$

3. In the sample or the population, there is no exact linear relationship among independent variables (no multicollinearity): none of the independent variables is constant, and there are no exact linear relationships among the independent variables.

4. The expected value of disturbances is zero or disturbances are not correlated with any regressors.

$$E(u|x_1 \dots x_k) = 0 \qquad \text{(Eq. 4)}$$

5. The error u has the same variance given any value of the independent variables.

$$Var(u|x_1 \dots x_k) = \sigma^2 \qquad \text{(Eq. 5)}$$

If individual effect u_{it} is not zero in panel data, heterogeneity (individual specific characteristics are not captured in independent variables) may influence assumption 4 and 5. And it is impossible to maintain the unit-specific effects equivalence, especially, disturbances may not share the same variance but vary across individual (heteroskedasticity, violation of assumption 5) and/or are related with each other (autocorrelation, violation of assumption 4) (Park, 2011).

$$u_{it} = u_i + v_{it} \qquad \text{(Eq. 6)}$$

Where u_i indicates the unobservable individual-specific effect and v_{it} indicates the remainder disturbance. And furthermore, disturbance term could be expressed as two-way error component term:

$$u_{it} = u_i + \lambda_t + v_{it} \qquad \text{(Eq. 7)}$$

Where u_i and v_{it} are the same as in (6). The extra component λ_t indicates the unobservable time effect. However, it is recommended that the researcher should start with the pooled OLS (POLS) as shown in (1).

In the POLS, the researcher continued the analysis with the assumption that there is neither significant individual effect nor time effect. However, in reality, the assumption is most likely violated. To compensate for that issue, the researcher applied fixed effects model that examines if intercepts vary across group and/or time period, whereas a random effects model explores differences in error variance components across individual or time period.

Woolridge listed the following assumptions for the individual fixed effects model (Wooldridge, 2013, p. 509):

Assumption FE. 1

For each i, the model is as the following:

$$y_{it} = \beta_1 * X_{it1} + \cdots + \beta_k * X_{itk} + \alpha_i + u_{it}, t = 1, \dots, T \qquad \text{(Eq. 8)}$$

Where the β_j are the parameters to estimate, and α_i is the unobserved effect specific to each individual.

Assumption FE. 2

It is a random sample from the cross section.

Assumption FE. 3

Each explanatory variable changes over time (for at least some i), and no perfect linear relationships exist among the explanatory variables.

Assumption FE. 4

For each t, the expected value of the idiosyncratic error given the explanatory variables in all time periods and the unobserved effect is zero:

$$E(u_{it}|X_i, \alpha_i) = 0 \qquad \text{(Eq. 9)}$$

Assumption FE. 5

$$Var(u_{it}|X_i, \alpha_i) = Var(u_{it}) = \sigma_u^2, for\ all\ t = 1, \dots, T. \qquad \text{(Eq. 10)}$$

Assumption FE. 6

For all $t \neq s$, the idiosyncratic errors are uncorrelated (conditional on all explanatory variables and a_i).

$$Cov(u_{it}, u_{is}|X_i, \alpha_i) = 0 \qquad \text{(Eq. 11)}$$

Assumption FE. 7

Conditional on X_i and a_i, the u_{it} are independent and identically distributed as Normal (0, σ_u^2). Woolridge (2013) suggested that the traditional way of fixed effects (FE) estimation could apply to both balanced panel data set and unbalanced panel data set. The functional form of a time fixed effects model, individual fixed effects model, and two ways fixed effects model for the static model are listed as follows:

$$y_{it} = \alpha_t + X'_{it} * \beta + u_{it} \qquad \text{(Eq. 12)}$$

$$y_{it} = \alpha_i + X'_{it} * \beta + u_{it} \qquad \text{(Eq. 13)}$$

$$y_{it} = \alpha_t + \alpha_i + X'_{it} * \beta + u_{it} \qquad \text{(Eq. 14)}$$

Besides fixed effects models, there is another panel data approach, the random effects model, to estimate the panel data, and it is built on the assumption that the unobserved effect a is uncorrelated with any independent variable, and to expand it, the random effects models are built on all the assumptions of the fixed effects model and the following random effects model assumption (Wooldridge, 2013, p. 510).

Assumption RE. 1

There are no perfect linear relationships among the explanatory variables.

Assumption RE. 2

In addition to FE.4, the expected value of a_i given all explanatory variables is constant:

$$E(\alpha_i|X_i) = \beta_0 \qquad \text{(Eq. 15)}$$

Assumption RE. 3

In addition to FE.5, the variance of α_i, given all explanatory variables is constant:

$$Var(\alpha_i|X_i) = \sigma_\alpha^2 \qquad \text{(Eq. 16)}$$

And under that circumstance, OLS is asymptotically unbiased but inefficient compared with feasible generalized least squares (FGLS). A proposed two ways random effects model developed by Swamy and Arora will be expressed as the following (1972):

$$y_{it} = \alpha + X'_{it} * \beta + (u_t + u_i + v_{it}) \qquad \text{(Eq. 17)}$$

Accident Rate Models

The following base POLS model was used to seek how the correlation between the independent variables might contribute to the variation of accident rates for airlines, and these are listed below.

$$AcciRate_i = \alpha + \beta_1 Omx_i + \beta_2 MtA_i + \beta_3 MxWage_i + \beta_4 Profitability_i + \beta_5 RtC_i + u_i \qquad \text{(Eq. 18)}$$

The above model assumed constant intercept and slopes regardless of airline and year. This model treated each data point as a simple random sample from the population, so the subscript i did not mean airline in the model. α is the disturbance/error term for the POLS model. And u_i was the disturbance/error term for the POLS model.

Furthermore, the researcher laid out three fixed effects models for the accident rate models in the order of time fixed effects model, individual fixed effects model, and two ways fixed effects model as the following:

$$AcciRate_{it} = \alpha_t + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 19)}$$

$$AcciRate_{it} = \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 20)}$$

$$AcciRate_{it} = \alpha_t + \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 21)}$$

In the above models: α_t varies with each year, and it showed the specific time (in this case: year) effect on the accident rate; α_i varies with each year, and it showed the time period (in this case: airline) effect on the accident rate. For β_1 to β_5, there were the coefficients denoting the specific independent effect on the accident rate. And the last term u_{it}, was the disturbance/error term for each model.

Finally, the researcher laid out a two ways random effects model in the following (Swamy & Arora, 1972):

$$AcciRate_{it} = \alpha + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + (u_t + u_i + v_{it}) \quad \text{(Eq. 22)}$$

In the above model: α was the constant intercept across airlines and years. For β_1 to β_5, there were the coefficients denoting the specific independent effect on the accident rate. The last group of errors were randomly distributed across years and airlines.

Incident Rate Models

The following base POLS model was used to seek whether the correlation between the independent variables might contribute to the variation of incident rate for the airlines, and these were listed below.

$$InciRate_i = \alpha + \beta_1 Omx_i + \beta_2 MtA_i + \beta_3 MxWage_i + \beta_4 Profitability_i + \beta_5 RtC_i + u_i \quad \text{(Eq. 23)}$$

The above model assumed a constant intercept and slope regardless of airlines and years. This model treats each data point as a simple random sample from the population, so the subscript i did not mean airline in the model. α is the disturbance/error term for the POLS model. And u_i was the disturbance/error term for the POLS model.

In addition, the researcher laid out three fixed effects models for the incident rate models in the order of an individual fixed effects model, time fixed effects model, and two ways fixed effects model as follows:

$$InciRate_{it} = \alpha_t + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 24)}$$

$$InciRate_{it} = \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 25)}$$

$$InciRate_{it} = \alpha_t + \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 26)}$$

In the above models: α_t varied with each year, and it showed the specific time period (in this case: year) effect on the incident rate: α_i varies with each airline, and it showed the individual time (in this case: airline) effect on the incident rate. For β_1 to β_5, there were the coefficients denoting the specific independent effect on incident rate. And last term u_{it}, was the disturbance/error term for each model.

Finally, the researcher laid out a two ways random effects model in the following (Swamy & Arora, 1972):

$$InciRate_{it} = \alpha + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + (u_t + u_i + v_{it}) \quad \text{(Eq. 27)}$$

In the above model: α was a constant intercept across airlines and years. For β_1 to β_5, there were the coefficients denoting the specific independent effect on the incident rate. The last group of errors were randomly distributed across year and airline.

Model Selection Tests

Poolability tests were deployed to test whether a FE model or POLS model was more suitable for the data, because it decided the slopes were the same across individual or/ and over time (Baltagi, 2005). In this stage of the research, a poolability test which was a simple extension of the Chow test could be used to accomplish the job (Chow, 1960; Park, 2011). The null hypothesis of the following formula-showing a poolability test of the individual fixed effects model, against the POLS model, was that all slopes of the independent variables are the same across individual (airlines).

$$F(n-1, nT-n-k) = \frac{\left[\frac{e' * e - \sum e_i' * e_i}{(n-1)(k+1)}\right]}{\left[\sum \frac{e_i' * e_i}{n(T-k-1)}\right]} \quad \text{(Eq. 28)}$$

In the above formula, $e' * e$ ws the Error Sum of Squares (SSE) of the pooled OLS and $e_i' * e_i$ was the SSE of the pooled OLS for individual airline i. When the null hypothesis was rejected, the panel data are not poolable; each individual had its own slopes for the independent variables.

By the same token, by comparing the SSE of the pooled OLS and SSE of the time fixed effects model, or by comparing the SSE of the pooled OLS and SSE of the two ways fixed effects model using F-test could be used to detect whether the POLS model or specific fixed effects model is more suitable for the data analysis.

It is very likely there are more than one fixed effects model that holds water by the criteria of each fixed effects model's p-value and p-value of the Chow F-test as described above (Park, 2011; Wooldridge, 2013). Reed and Ye (2009) suggested the researcher use the most efficient model to determine the best model which is the one with the lowest root mean square error. The root-mean-square-error (RMSE) was expressed in the following equation.

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{\hat{y_i} - y_i}{n}} \qquad \text{(Eq. 29)}$$

The researcher would use the RMSE method to select the best fixed effects model.

To test whether a RE model or POLS model is more suitable for the data, the researcher would conduct a Lagrange multiplier (LM) test proposed by Breusch and Pagan (1980) to examine if individual or (time) specific variances are zero as null hypothesis, and the LM statistic follows the chi-square distribution with one degree of freedom (Park, 2011, p. 12).

$$LM_u = \frac{nT}{2(T-1)}\left[\frac{T^2 \bar{e}' \bar{e}}{e'e} - 1\right] \sim \chi^2\ (1) \qquad \text{(Eq. 30)}$$

Where $\bar{e}$ was n $n * 1$ vector of the group means of pooled regression residuals, and $e'e$ was the SSE of the pooled OLS regression. Provided that the null hypothesis is rejected, the researcher can conclude that there is a significant random effect in the panel data, and the random effects model should be favored over the POLS for the RE model's ability to deal with heterogeneity.

If there are fixed effects models and random effects models left, and the Hausman specification test can be used to compare the fixed and random effects models under the null hypothesis that individual effects are uncorrelated with any independent variables in the model (Hausman, 1978), $\widehat{\beta_{FE}}$ $and\ Var\left(\widehat{\beta_{FE}}\right)$ indicate the FE estimators and its variance matrix and likewise for the RE estimator $\widehat{\beta_{RE}}$ $and\ Var\left(\widehat{\beta_{RE}}\right)$. If the RE model is correct, $\widehat{\beta_{FE}}$ is consistent and efficient indicating $Var\left(\widehat{\beta_{RE}}\right) > Var\left(\widehat{\beta_{FE}}\right)$. Suppose $q = \widehat{\beta_{FE}} - \widehat{\beta_{RE}}$, and under the null hypothesis it follows that, $cov(\widehat{\beta_{FE}} - \widehat{\beta_{RE}})$=0. And the variance of the difference is:

$$Var(\hat{q}) = Var\left(\widehat{\beta_{FE}}\right) - Var\left(\widehat{\beta_{RE}}\right) \qquad \text{(Eq. 31)}$$

If the individual effects are not random but correlated with the independent variables then the RE estimates are inconsistent, but the FE estimates are still consistent since the FE model admits any degree of correlation between intercept term and independent variable. The Hausman test includes an intercept and dummy variables, and the test statistic follows the chi-squared distribution with k degrees of freedom.

$$H = q'[Var(\hat{q})]^{-1}q \sim \chi^2\ (k) \qquad \text{(Eq. 32)}$$

By rejection of the null hypothesis of no correlation between the unobserved individual specific random effects and the independent variables, the researcher would conclude that individual effects u_i are significantly correlated with at least one independent variable in the model and thus the random effects model is not fit for the dataset. The researcher would use fixed effects model.

Reliability and Validity of the First Stage Research

The key components reliability are consistency and stability (Gubrium et al., 2012; Heale & Twycross, 2015; Leung, 2015; Salkind, 2010; Sekaran & Bougie, 2016). Sekaran and Bougie maintain that , “Reliability attests to the consistency and stability of the measuring instrument” (2016, p. 396).

Validity in quantitative research monitors whether the tests or instruments researchers are using actually measure what they intend to measure (Salkind, 2012). Sekaran and Bougie define validity as, “Evidence that the instrument, technique, or process used to measure a concept does indeed measure the intended concept” (2016, p. 398). Econometrics research divides validity in to two areas, internal validity and external validity like in the first stage of a research project. Stock and Watson (2003) maintain that internal validity lies in the causal effects ascertained by the econometrical models in the sample as these extend to the population, and external validity is established when the statistical inferences can be generalized from the population and setting studied and are applied to other populations and settings.

Together, reliability and validity in quantitative research are considered as a goodness of measures (Sekaran & Bougie, 2016).

Regarding econometrical regression analysis, Stock and Watson (2003) observed that there are five threats to internal validity based on OLS regression studies:

1. Omitted variable bias happens when a variable that both determines the dependent variable and is correlated with one or more of the included independent variables that is omitted from the regression.
2. Wrong functional form occurs when the functional form of the estimated regression function differs from the functional form of the population regression function.
3. Errors-in-variables bias occurs when an independent variable is measured imprecisely.
4. Sample selection bias occurs when the data are missing because of a selection process that is related with the value of the dependent variable, beyond depending on the independent variables; then this selection process can introduce a correlation between the error term and the independent variables.
5. Simultaneous causality bias is the uncertainty of causality between independent variables and dependent variables.

The independent variables correlating with error terms resulting from omitted variable bias, errors-in-variable bias, and/or simultaneous causality are commonly known as the endogenous variables.

For the current research, the data collected and the tests that were performed were verified as both reliable and valid. The first stage research data was obtained from impartial U.S. government agencies including the FAA, the NTSB, the DOT, the U.S. Securities and Exchange Commission, and the Federal Reserve and verified by professionally recognized higher education institutes such as MIT as well as the researcher. Thus, the researcher was able to minimize the error-in-variables bias by using finely recorded high-quality data. As discussed in Chapter 3, the POLS, FE, and RE models and the tests including t-test, F-test, Breusch Pagan LM test, or Hausman test are commonly used econometric tools to analyze panel data (Baltagi, 2005; Stock & Watson, 2003; Wooldridge, 2013). Stock and Watson (2003) claimed that the fixed effects panel data regression can overcome omitted variable bias as long as the omitted variables stay constant over time. In this research, the population with respect to internal validity consisted of 15 major U.S. passenger airlines operating between1995 and 2019, and the sample consisted of the eight continuously operating airlines among the population. Other potential populations with respect to external validity included the world's major passenger airlines such as Air China, Lufthansa, and Air France, etc. As a result, internal validity was established. However, due to the small sample size of the dataset and the capricious and multifaceted nature of airline operations across borders, business models, and other factors, the researcher could not ascertain the external validity of the research (Belobaba et al., 2016; Bruce et al., 2018; Helmreich, 1998; Porter, 1980; Williams, 2020; Wooldridge, 2013).

Second Stage: Qualitative Research

The second, qualitative phase of the research obtained in the first, quantitative phase concentrated on verifying and explaining the results of the econometrical tests, opinions and understandings of current commercial aircraft maintenance practices, and their expectations of the industry. It consisted of the interviews, and analysis of the interview transcripts.

Population and Sample of the Qualitative Research

The population in the second stage of the qualitative research included aviation maintenance professionals and other stakeholder whose work deals with commercial aircraft maintenance and affect aviation safety. The sample for the second stage of the research included commercial aircraft maintenance professionals including, but not limited to, aircraft maintenance personnel in the airlines or repair stations, and management personnel, safety inspectors affiliated with Chinese and U.S. civil aviation authorities, and other stakeholders who were not working within the aviation sector but had interest in it. The researcher began to interview these subjects drawing on a convenience sample of several aircraft maintenance professionals provided by the committee members and researcher. Afterwards these interviewees were asked to provide contact information for suitable interview candidates within or outside the organizations to increase the sample size; this method is known as the snowball sampling technique (Lohr, 2010). The sample size is limited to a saturation point with an appearance of "information redundancy, not a statistical confidence level" (Lincoln & Guba, 1985, p. 202). Information redundancy in the interview happens when the researchers get the same responses to the interview questions from different interviewees (Merriam, 2016).

In order to obtain more comprehensive results from the research, the researcher made attempts to interview not only lower level employees, but also higher level stakeholders in their organizations such as senior vice president of technical operations, directors of maintenance, base managers, and other management level officials because “just as those who draw landscapes place themselves below the plain to contemplate the nature of the mountains and of lofty places, and in order to contemplate the plains place themselves upon high mountains” (Machiavelli, 1532/2017, p. 4).

Ethical Assurance

Human subjects were an essential part of the second stage of research. The second stage research was conducted in accordance with IRB requirements established by Purdue’s Institutional Review Board (IRB). The researcher obtained IRB approval from Purdue's Human Research Protection Program before conducting any research and gathering data. The researcher and his committee were morally responsible for conducting research in a way that minimizes any imaginable harm to those involved in this stage of the research. The interview fell into the Category 2 of human subjects’ research (Purdue University Internal Review Board, 2019). A detailed consent and invitation to participate in the research are attached in Appendix B.

Treatment and Instrumentation of the Qualitative Research

The primary technique in this stage involved the interviews with commercial aircraft maintenance professionals who work in different capacities in the U.S. and China, and other stakeholders. The interviews filled potential voids by connecting the literature review, the first stage research results, visceral feelings, and work experiences to reach a holographic understanding of the esoteric matter (Creswell, 2018; Lincoln & Guba, 1985; Mao, 1965). In this research, the esoteric matter involved the true effects on aviation safety caused by airline maintenance outsourcing and loopholes, deficiencies, concerns, and barriers as well as opportunities related to airline maintenance outsource issues. The interviews included synchronously online semi-structured interviews to answer the research questions.

Assumption for the Qualitative Research

The researcher made one assumption for the qualitative study. The assumption is that the interviewees respond honestly and accurately.

Reliability and Validity of the Second Stage Research

In qualitative research, Lincoln and Guba referred to reliability, internal validity, and external validity as credibility, consistency/dependability, and transferability (Lincoln & Guba, 1985). Common threats to reliability and validity in qualitative research are presented in the following questions collected by Merriam (2016, p. 254).

1. *What can you possibly tell from an n of 1 (3, 15, 29, and so on)?*
2. *What is it worth just to get the researcher's interpretation of the participant's interpretation of what is going on?*
3. *How can you generalize from a small, nonrandom sample?*
4. *If the researcher is the primary instrument for data collection and analysis, how can we be sure the researcher is a valid and reliable instrument?*
5. *How will you know when to stop collecting data?*
6. *Isn't the researcher biased and just finding out what he or she expects to find?*
7. *Without hypotheses, how will you know what you are looking for?*
8. *Doesn't the researcher's presence result in a change in participants' normal behavior, thus contaminating the data?*
9. *Don't people often lie to field researchers?*
10. *If somebody else did this study, would they get the same results?*

Internal validity is concerned with how the research questions match with reality. Merriam (2016) listed the following four strategies to improve the internal validity of the qualitative research: triangulation, member checks (respondent validation), adequate engagement in data collection, researcher’s position or reflexivity, and peer examination (peer review). For a singular research like this one, a powerful strategy known as triangulation includes more than one data collection method (quantitative and qualitative), multiple sources of data, or multiple theories to increase the credibility or internal validity of the research. Researchers use member checks to obtain feedback on the preliminary or emerging findings from some of the researcher participants from whom they have collected primary data. Adequate engagement in data collection occurs when the researchers continue to collect data until the point of "saturation"- when the researcher does not acquire any new information from the data collection process.

Reflexivity refers to the researcher's "need to explain their biases, dispositions, and assumptions regarding the research to be undertaken" (Merriam, 2016, p. 260). Peer examination is a strategy that the researchers use to show the preliminary research to the peers or committee members and seek feedback and commentary from them.

Merriam (2016) listed the following strategies to ensure consistency and dependability or reliability: triangulation, peer examination, reflexivity, and the audit trail. The first three strategies could be in reference to the previous paragraph. An audit trail, suggested by Lincoln and Guba (1985), is a strategy where researchers keep a detailed journal of the methods, procedures, and decision points in carrying out the study.

External validity is synonymous with generalizability: whether the research findings can be applied to another setting (Merriam, 2016; Sekaran & Bougie, 2016). Merriam listed the following strategies to ensure external validity: use of a rich, thick description and maximum variation (2016). Rich, thick description means that the researchers supply enough description to contextualize the study insomuch that the readers will make a judgment call of their situation matching the research context, and a consequent decision whether the findings are transferrable (Lincoln & Guba, 1985). Maximum variation is a strategy, "Purposefully seeking variation or diversity in sample selection to allow for a greater range of application of the findings by consumers of the research" (Merriam, 2016, p. 268).

The reliability and verification techniques of the second stage of research included peer examination, member check, and triangulation. The verification techniques of reliability and validity were applied to the research in the following steps: peer examination of the interview questions and simulated interviews, semi-structed interview, and triangulation.

Step one (peer examination) involved the committee members who investigate, authenticate, and revise research questions proposed by the researcher. If deemed necessary and time allowed, mock-up interviews were conducted with the research questions to obtain additional feedback to increase the credibility of the instrument (Merriam, 2016).

Step two involved semi-structured interviews with the commercial aircraft maintenance professionals and its stakeholders. The audios of these interviews were recorded, and the interview scripts produced by the researcher were sent back to the interviewees for member checks for accuracy of the manuscripts and any changes concerning the interview data.

Step three was a process known as coding, the researcher used Microsoft Excel, Word, and NVivo application to classify responses from the interviewees into particular themes. Coding enables researcher to develop, manage, classify raw data, and answer questions in an analytical way (Lincoln & Guba, 1985; Merriam, 2016).

Finally, the researcher used these qualitative research findings to refine and explain the statistical results of the first quantitative research effect of passenger airline aircraft and maintenance outsourcing on the aviation safety of passenger airline aircraft, as well as constructing recommendations for the improvement of aviation safety and airline maintenance and provide guidance for future research.

Summary

The first part of chapter explored quantitative, qualitative, and mixed methods research, and illustrated the rationale for the selection of explanatory sequential mixed methods research for this study, and the worldview of the researcher while conducting the research. The second part of the chapter discussed these aspects for the first stage of the quantitative research: dependent variables and independent variables selection, population and sample, ethical assurance, assumptions, models and final model selection process, and it concluded with a discussion of reliability and validity for the first stage of quantitative research. The third and final part of chapter discussed the following aspects of the second stage of the quantitative research: population and sample, ethical assurance, treatment and instrumentation used, assumptions, and it concluded with a discussion of the reliability and validity of the second stage qualitative research. The next chapter will present the first stage quantitative research results and analysis.

CHAPTER 4. FIRST STAGE RESULTS AND ANALYSIS

Descriptive Statistics

The tables below show the descriptive statistics of the dependent and independent variables used to build the models in the study.

Table 10 *Descriptive Statisitics of Dependent Variables*

	AcciRate	InciRate
Mean	1.55396E-06	1.18721E-06
Standard Deviation	3.26274E-06	2.94415E-06
Minimum	0	0
Maximum	3.04804E-05	2.32769E-05
Count	200	200

Table 11 *Descriptive Statisitics of Independent Variables from Original Data*

	Omx	MtA	MxWage	Profitability	RtC
Mean	0.470381	9.888325	82999.34	0.043221759	44779.73
Standard Deviation	0.212716	6.182407	95584.57	0.102006346	10495.08
Minimum	0.000653	1	24196.46	-0.216921291	27854.02
Maximum	1.374506	28	755503.10	0.314895732	64041.32
Count	193	197	197	200	25
Missing Percentage	4%	2%	2%	0%	0%

For the Percent of Maintenance Expenses Outsourced (Omx), observations were missing for Frontier Airlines between 1995 and 1997 as well as for Spirit Airlines between 1995 and 1998. Hence, the total missing observations of Omx total seven. For the rounded-up Inhouse maintenance labor to aircraft ratio (MtA) and real Average annual wages and salaries - inhouse maintenance personnel (MxWage), there were missing observations for Southwest Airlines in 1998, Spirit Airlines in 1998, and Hawaii Airlines in 2008, respectively. The missing observations of MtA were due to the missing observations of total in-house maintenance employee equivalents for the airlines in these years. Thus, the total missing observations of MtA and MxWage total three, respectively. The researcher used mean imputation of the variables to solve the problem of the missing observations, since none of the missing data have surpassed 5% (Jakobsen et al., 2017). The last independent variable real GDP per capita (RtC) was a time specific variable, which means it is observed the same for all the airlines between 1995 and 2019, and consequently there are 25 observations in total.

Accident Rate Model Outputs

The correlation matrix of the independent variables in the model is listed below.

Table 12 *Correlation Matrix: Independent Variables*

	Omx	MtA	MxWage	Profitability	RtC
Omx	1				
MtA	0.4034	1			
MxWage	0.0687	0.3317	1		
Profitability	-0.0015	0.1926	-0.01400135	1	
RtC	0.0607	0.0827	0.08914724	-0.42540334	1

The variance inflation factor was calculated for all the independent variables for testing multicollinearity; it ranged from 1.14 to 1.45 with a mean value of 1.28.

Table 13 *VIF: Independent Variables*

Independent Variables	Omx	MtA	MxWage	Profitability	RtC
VIF	1.21	1.45	1.14	1.32	1.27

As a rule of thumb, the cutoff variable inflation factor is ten, which suggests the independent variables selected by the current research are not colinear (O’ Brien, 2007).

The researcher has used three different models to analyze the panel data set: the POLS model (pooling), the fixed effects model (within), and the error components model (random) (Croissant & Millo, 2008). All the formula of models and models’ results are presented as follows:

$$AcciRate_i = \alpha + \beta_1 Omx_i + \beta_2 MtA_i + \beta_3 MxWage_i + \beta_4 Profitability_i + \beta_5 RtC_i + u_i$$
(Eq. 33)

Table 14 *Accident Rate POLS Model*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Constant	4.72E-06	1.51E-06	3.1341	0.001991**
Omx	-1.74E-06	1.20E-06	-1.4485	0.149104
MtA	-7.44E-08	4.48E-08	-1.661	0.098332
MxWage	-1.08E-12	2.57E-12	-0.4206	0.674518
Profitability	-4.91E-06	2.57E-06	-1.9122	0.057329
RtC	-2.91E-11	2.49E-11	-1.1703	0.243329
TSS	2.12E-09			
RSS	2.01E-09			
R-Squared	0.0507			
Adj. R-Squared	0.026233			
F-statistic	2.07222 on 5 and 194 DF			
p-value	0.070523			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Accident rate for the POLS model indicated that the model failed to establish a statistically significant correlation between the independent variables and the dependent variable.

$$AcciRate_{it} = \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it}$$
(Eq. 34)

Table 15 *Accident Rate Individual Fixed Effects Model*

Coefficients	Estimate	SE	t-value	Pr(>|t|)
Omx	-8.17E-07	1.58E-06	-0.5174	0.60548
MtA	-1.29E-07	7.78E-08	-1.6548	0.09964
MxWage	-7.67E-13	2.74E-12	-0.2799	0.77988
Profitability	-3.54E-06	2.67E-06	-1.3254	0.18664
RtC	-4.03E-11	2.61E-11	-1.5454	0.12394
TSS	2.00E-09			
RSS	1.91E-09			
R-Squared	0.044984			
Adj. R-Squared	-0.016301			
F-statistic	1.76163 on 5 and 187 DF			
p-value	0.12272			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom.
legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Accident rate for the individual fixed effects model indicated that the model failed to establish statistically significant correlation between the independent variables and the dependent variable.

$$AcciRate_{it} = \alpha_t + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it}$$
(Eq. 35)

Table 16 *Accident Rate Time Fixed Effects Model*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Omx	-1.73E-06	1.22E-06	-1.4101	0.1603248
MtA	-9.89E-08	4.73E-08	-2.0885	0.0382313*
MxWage	-2.34E-12	2.76E-12	-0.8476	0.3978295
Profitability	-1.32E-05	3.59E-06	-3.6744	0.0003188***
TSS	1.83E-09			
RSS	1.68E-09			
R-Squared	0.082867			
Adj. R-Squared	-0.067307			
F-statistic	3.86266 on 4 and 171 DF			
p-value	0.0049619			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Accident rate time fixed effects model indicated that the model established a statistically significant correlation between the independent variables and the dependent variable. Among the independent variables, MtA and Profitability were statistically significant and could explain the dependent variable-Accident rate in the model.

$$AcciRate_{it} = \alpha_t + \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 36)}$$

Table 17 *Accident Rate Two Ways Fixed Effects Model*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Omx	-1.37E-06	1.65E-06	-0.8288	0.408424
MtA	-1.03E-07	8.56E-08	-1.2039	0.230369
MxWage	-1.49E-12	3.03E-12	-0.4913	0.623888
Profitability	-1.19E-05	4.01E-06	-2.9736	0.003387**
TSS	1.71E-09			
RSS	1.61E-09			
R-Squared	0.060251			
Adj. R-Squared	-0.14031			
F-statistic	2.62867 on 4 and 164 DF			
p-value	0.036375			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Accident rate two ways fixed effects model indicated that the model established a statistically significant correlation between the independent variables and the dependent variable. Profitability was the only statistically significant independent variable to explain the dependent variable-Accident Rate in the model.

$$AcciRate_{it} = \alpha + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + (u_t + u_i + v_{it}) \quad \text{(Eq. 37)}$$

Table 18 *Accident Rate Random Effects Model*

Independent Variables	Estimate	SE	z-value	Pr(>|z|)
Constant	4.75E-06	1.59E-06	2.9933	0.002759**
Omx	-1.56E-06	1.31E-06	-1.1884	0.234684
MtA	-7.99E-08	5.19E-08	-1.541	0.123324
MxWage	-7.75E-13	2.61E-12	-0.2976	0.766038
Profitability	-4.46E-06	2.58E-06	-1.7242	0.084679
RtC	-3.16E-11	2.49E-11	-1.2697	0.204201
TSS	2.07E-09			
RSS	1.97E-09			
R-Squared:	0.045955			
Adj. R-Squared	0.021366			
Chisq	9.34472 on 5 DF			
p-value	0.09608			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, DF stands for degrees of freedom, and Chisq means Chi-square's score. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Accident rate random effects model indicated that the model failed to establish statistically significant correlation between the independent variables and the dependent variable.

By comparing the p-value of each model to the conventional significance level ($\alpha = 0.05$), the researcher concluded that the Accident rate POLS model, the Accident rate individual fixed effects model, and the Accident rate random effects model were not suitable for analysis of this data set because their p-value of each model was greater than 0.05. These three models were not statistically significant and indicate strong evidence for the null hypothesis. In other words, there was no cross-section data effect for the data set, there were no individual fixed effects existent for the data set, and there were no random effects existent for the data set.

The researcher proceeded to use the Root Mean Square Error (RMSE) to compare the time fixed effects model and two-way fixed effects model. The RMSE for each model is presented below.

Table 19 *RMSE Comparison of the Fixed Effects Model*

	Accident Rate Time Fixed Effects Model	Accident Rate Two Ways Fixed Effects Model
RMSE	3.49978E-06	3.53419E-06

Finally, the researcher chose the time fixed effects model as the ultimate model to show a correlation between the independent variables and the accident rate because it had the smallest RMSE value. The full results of the Accident rate time fixed effects model are shown in the table below.

Table 20 *Accident Rate Time Fixed Effects Model Full Results*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Omx	-1.73E-06	1.22E-06	-1.4101	0.1603248
MtA	-9.89E-08	4.73E-08	-2.0885	0.0382313*
MxWage	-2.34E-12	2.76E-12	-0.8476	0.3978295
Profitability	-1.32E-05	3.59E-06	-3.6744	0.0003188***
1995	-1.05E-06	1.40E-06	-0.7488	0.45502
1996	3.07E-06	1.45E-06	2.1239	0.03511*
1997	2.80E-06	1.50E-06	1.8608	0.06448
1998	7.68E-07	1.68E-06	0.4569	0.64833
1999	5.69E-08	1.76E-06	0.0323	0.97428
2000	1.91E-06	1.65E-06	1.1567	0.249
2001	-1.94E-06	1.50E-06	-1.298	0.19604
2002	-2.05E-06	1.51E-06	-1.3559	0.17693
2003	5.22E-07	1.48E-06	0.353	0.72453
2004	-1.91E-06	1.51E-06	-1.2594	0.20959
2005	-5.27E-07	1.46E-06	-0.3611	0.71846
2006	-1.55E-06	1.48E-06	-1.0453	0.29736
2007	-1.11E-06	1.46E-06	-0.7609	0.44776
2008	-2.42E-06	1.45E-06	-1.6635	0.09805
2009	-9.73E-07	1.47E-06	-0.6603	0.50995
2010	2.21E-07	1.44E-06	0.1534	0.87824
2011	-9.06E-07	1.41E-06	-0.6405	0.5227
2012	-6.38E-07	1.44E-06	-0.4432	0.65816
2013	-7.93E-07	1.52E-06	-0.5205	0.60342
2014	2.03E-07	1.56E-06	0.1306	0.89623
2015	1.69E-06	1.75E-06	0.9637	0.33656
2016	1.30E-06	1.69E-06	0.7694	0.44272
2017	1.12E-06	1.61E-06	0.6941	0.48857
2018	8.80E-07	1.52E-06	0.5785	0.56366
2019	1.33E-06	1.56E-06	0.852	0.39538
TSS	1.83E-09			
RSS	1.68E-09			
R-Squared	0.082867			
Adj. R-Squared	-0.067307			
F-statistic	3.86266 on 4 and 171 DF			
p-value	0.0049619			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

In the model, only the MtA, Profitability, and the year 1996 had strong statistically significant correlation with the accident rate. The researcher interpreted these variables as follows: Holding Omx (Percent of Maintenance Expenses Outsourced), MxWage (average annual wages and salaries - inhouse maintenance personnel), and Profitability (airline profitability adjusted for inflation), and the time constant, additional one inhouse maintenance labor to aircraft was associated with roughly ten less counts of accidents per one hundred million block hours of flights on average. Holding Omx, MtA, MxWage, and time constant, one percentage point of increase in Profitability was associated with roughly one less count of accidents per one hundred thousand block hours of operation on average. Holding Omx, MtA, MxWage, and the Profitability constant, the year 1996 had roughly three more counts of accidents per one million block hours of flight on average.

Although these three coefficients were too small, and they rendered little practical significance, the ratio among these coefficients were dramatically different as listed in the table below. This difference was an interesting indication of a relatively large difference of parameters' impacts on aviation accidents. These results were addressed by the interviewees in the second stage-qualitative research.

Table 21 *Accident Rate Time Fixed Effects Model Results Comparison*

	MtA	Profitability	1996
MtA	1		
Profitability	133.50	1	
1996	-31.07	-0.23	1

Incident Rate Model Outputs

The following base model was used to seek the correlation between the variables related to aircraft maintenance outsourcing and how it might contribute to the variation of the incident rate for sample airlines and is listed below.

The researcher used the same set of independent variables, and the reader can refer to the independent variable correlation matrix and the VIF of the independent variables shown in the previous section: Accident rate model outputs.

Similarly, the researcher has used three different models to analyze the panel dataset: the POLS model (pooling), the fixed effects model (within), and the error components model (random) (Croissant & Millo, 2008). All the models' results were presented in the following tables.

$$IncıRate_i = \alpha + \beta_1 Omx_i + \beta_2 MtA_i + \beta_3 MxWage_i + \beta_4 Profitability_i + \beta_5 RtC_i + u_i \quad \text{(Eq. 38)}$$

Table 22 *Incident Rate POLS Model Results*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Constant	4.21E-06	1.32E-06	3.183	0.001698**
Omx	9.98E-07	1.06E-06	0.9435	0.346605
MtA	-4.92E-08	3.94E-08	-1.2478	0.213598
MxWage	1.67E-12	2.26E-12	0.7372	0.461895
Profitability	-2.51E-06	2.26E-06	-1.1103	0.268244
RtC	-6.79E-11	2.19E-11	-3.0982	0.002236**
TSS	1.72E-09			
RSS	1.56E-09			
R-Squared	0.0977			
Adj. R-Squared	0.074445			
F-statistic	4.20123 on 5 and 194 DF			
p-value	0.0011983			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Incident rate POLS model indicated that the model established a statistically significant correlation between the independent variables and the dependent variable. Among the independent variables, the Constant term and RtC were statistically significant to explain the dependent variable-Incident Rate in the model.

$$IncíRate_{it} = \alpha_t + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it}$$
(Eq. 39)

Table 23 *Incident Rate Time Fixed Effects Model Results*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Omx	9.53E-07	1.12E-06	0.8484	0.39739
MtA	-6.86E-08	4.35E-08	-1.5776	0.11652
MxWage	8.80E-13	2.54E-12	0.3472	0.72885
Profitability	-6.60E-06	3.30E-06	-1.9999	0.04709*
TSS	1.49E-09			
RSS	1.42E-09			
R-Squared	0.049357			
Adj. R-Squared	-0.1063			
F-statistic	2.21955 on 4 and 171 DF			
p-value	0.068893			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Incident rate time fixed effects model indicated that the model failed to establish a statistically significant correlation between the independent variables and the dependent variable.

$$InciRate_{it} = \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it}$$

(Eq. 40)

Table 24 *Incident Rate Individual Fixed Effects Model Results*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Omx	8.19E-07	1.40E-06	0.5841	0.559874
MtA	-6.78E-08	6.90E-08	-0.9825	0.327119
MxWage	1.27E-12	2.43E-12	0.5218	0.602451
Profitability	-1.51E-06	2.37E-06	-0.6369	0.524976
RtC	-7.41E-11	2.31E-11	-3.2049	0.001589**
TSS	1.64E-09			
RSS	1.50E-09			
R-Squared	0.085176			
Adj. R-Squared	0.02647			
F-statistic	3.48216 on 5 and 187 DF			
p-value	0.0049377			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Incident rate fixed effects model indicated that the model established a statistically significant correlation between the independent variables and the dependent variable. Among the independent variables, only RtC was statistically significant to explain the dependent variable-Incident Rate in the model.

$$InciRate_{it} = \alpha_t + \alpha_i + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + u_{it} \quad \text{(Eq. 41)}$$

Table 25 *Incident Rate Two Ways Fixed Effects Model Results*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Omx	5.39E-07	1.52E-06	0.3539	0.7238
MtA	-8.59E-08	7.90E-08	-1.0876	0.2784
MxWage	3.79E-13	2.80E-12	0.1353	0.8925
Profitability	-5.22E-06	3.70E-06	-1.4095	0.1606
TSS	1.41E-09			
RSS	1.37E-09			
R-Squared	0.02599			
Adj. R-Squared	-0.18188			
F-statistic	1.09402 on 4 and 164 DF			
p-value	0.36133			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Incident rate two ways fixed effects model indicated that the model failed to establish a statistically significant correlation between the independent variables and the dependent variable.

$$InciRate_{it} = \alpha + \beta_1 Omx_{it} + \beta_2 MtA_{it} + \beta_3 MxWage_{it} + \beta_4 Profitability_{it} + \beta_5 RtC_{it} + (u_t + u_i + v_{it}) \quad \text{(Eq. 42)}$$

Table 26 *Incident Rate Random Effects Model Results*

Independent Variables	Estimate	SE	z-value	Pr(>|z|)
Constant	4.22E-06	1.33E-06	3.1811	0.001467**
Omx	9.93E-07	1.06E-06	0.9342	0.350212
MtA	-4.93E-08	3.97E-08	-1.2422	0.214168
MxWage	1.66E-12	2.26E-12	0.7338	0.463101
Profitability	-2.49E-06	2.26E-06	-1.0991	0.271719
RtC	-6.80E-11	2.19E-11	-3.1036	0.001912**
TSS	1.72E-09			
RSS	1.56E-09			
R-Squared	0.097338			
Adj. R-Squared	0.074074			
Chisq	20.9199 on 5 DF			
p-value	0.00083877			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, DF stands for degrees of freedom, and Chisq means Chi-square score. legend: *p < .05; **p < .01; ***p < .001.

The p-value of the Incident rate random effects model indicated that the model established a statistically significant correlation between the independent variables and the dependent variable. Among the independent variables, the constant term and RtC were statistically significant to explain the dependent variable-Incident Rate in the model.

By comparing the p-value of each model to the conventional significance level ($\alpha = 0.05$), the researcher concludes that the incident rate time fixed effects model and the incident rate two ways fixed effects model were not suitable for analysis of this data set because their p-value was greater than 0.05. These two models were not statistically significant and indicated strong evidence for the null hypothesis. In other words, there are no time fixed effects existent for the data set, and there were no two ways fixed effects existent for the data set.

The F test was used to compare the fixed effects models against the POLS model, which is a simple Chow test with the restricted residual sums of squares being that of OLS on the pooled model and the unrestricted residual sums of squares being that of the fixed effects model (Chow, 1960; Torres-Reyna, 2010). In this case, the practical meaning of the null hypothesis of the F test was that there were no significant individual fixed effects, and the POLS model was better than the individual fixed effects model. The results are presented in the table below.

Table 27 *Incident Rate Individual Fixed Effects Models versus Incident Rate POLS Model Results*

	F test for individual effects
F	0.91902
DF1	7
DF2	187
p-value	0.4929

Note. DF1 means the degrees of freedom for the numerator, DF2 means the degrees of freedom for the denominator.

The results indicated that the researcher should reject null hypothesis and choose the Incident rate individual fixed effects model over the Incident rate POLS model for this data set.

Breusch-Pagan LM test was used to compare the random effects model against the POLS model (Breusch & Pagan, 1980). The practical meaning of the null hypothesis of the Breusch-Pagan LM was that no significant difference across units and the POLS model was sufficiently good for analyzing the data (Torres-Reyna, 2010). And the results of Breusch-Pagan LM test are listed in the table below.

Table 28 *Breusch-Pagan LM Test for Incident Rate Random Effects Model*

	Breusch-Pagan LM Test Results
F	1.9281
df	2
p-value	0.3813

Based on the above results, the researcher failed to reject the null hypothesis and concluded that the Incident rate random effects model is not appropriate, therefore it is better to run a simple OLS regression. However, the researcher has previously identified that the Incident rate individual fixed effects model was better than the Incident rate POLS model.

Finally, the researcher chose the individual fixed effects model as the ultimate model to show a correlation between the independent variables and the incident rate. The researcher proceeded to show the full results of Incident rate fixed effects model in the table below.

Table 29 *Incident Rate Individual Fixed Effects Model Full Results*

Independent Variables	Estimate	SE	t-value	Pr(>|t|)
Omx	8.19E-07	1.40E-06	0.5841	0.559874
MtA	-6.78E-08	6.90E-08	-0.9825	0.327119
MxWage	1.27E-12	2.43E-12	0.5218	0.602451
Profitability	-1.51E-06	2.37E-06	-0.6369	0.524976
RtC	-7.41E-11	2.31E-11	-3.2049	0.001589**
Alaska	2.63E-07	1.61E-06	0.1628	0.8709
American	1.94E-07	2.13E-06	0.0912	0.9274
Delta	5.88E-08	1.72E-06	0.0342	0.9728
Frontier	8.28E-07	1.53E-06	0.5428	0.5879
Hawaiian	3.31E-07	1.86E-06	0.1784	0.8586
Southwest	-8.77E-07	1.53E-06	-0.5724	0.5677
Spirit	-7.50E-07	1.52E-06	-0.4926	0.6229
United	-4.77E-08	1.85E-06	-0.0258	0.9794
TSS	1.64E-09			
RSS	1.50E-09			
R-Squared	0.085176			
Adj. R-Squared	0.02647			
F-statistic	3.48216 on 5 and 187 DF			
p-value	0.0049377			

Note. SE stands for standard error, TSS stands for total sum of squares, RSS stands for residual sums of squares, and DF stands for degrees of freedom. legend: *p < .05; **p < .01; ***p < .001.

In this model, only the RtC (Real GDP per Capita) had a strong statistically significant correlation with the incident rate. The researcher interpreted its effect as the following: holding Omx, MtA, MxWage, Profitability, airlines constant, one dollar increase in RtC will be associated with roughly 7 less counts of incidents per one hundred billion block hours on average. This coefficient for RtC was very small, and it rendered little practical meaning.

Summary

To sum up the results of the accident rate model and incident rate model in layman's language, for the major mainline U.S. airlines between 1995 and 2019, the researcher concluded the first stage research with the following results listed by its magnitude of impact on aviation safety:

- Air travel is safer when the airline makes more money.
- Air travel is safer when the airline assigns more maintenance personnel to each aircraft.
- Air traveler is safer when the real GDP per capita is higher.
- Air travel safety is uncorrelated with percent of maintenance expenses outsourced.
- Air travel safety is uncorrelated with airline inhouse maintenance pay.

CHAPTER 5. SECOND STAGE RESULTS AND ANALYSIS

Interviewees' Background Data

This stage of the study conducted eight semi-structured interviews with interviewees based in the U.S. and Greater China. To introduce the reader to an idea of the interviewees' backgrounds, the following tables list basic information about them as extracted from the interviews.

Sub-question 1: What is your background (demographic, the organizations/companies you have served/ are serving, technical skills, experience, and whether they are affiliated with labor union)?

The first question was intended to help the researcher know the interviewees well, so that he could tailor specific details in the follow-up interviews. The interviewees' responses were presented in the following table.

Table 30 *Background Information about Interviewees*

Name	Gender	Education	Certification
interviewee1	Female	BS, Social Sciences; LLB, Law	Bar
interviewee2	Male	BS & MS Aviation Management	
interviewee3	Male	BS, Flight Vehicle Propulsion Engineering; MBA	Regulator1 Mechanic License
interviewee4	Male	BS, Flight Vehicle Propulsion Engineering	Regulator1 Turbofan Engine
interviewee5	Male	BS, Instruments Design; MS, Aviation Management	Regulator1 Avionics; Lawyer License
interviewee6	Male	BS, Electronics Engineering	Regulator1 Base & management personnel certificate
interviewee7	Male	BS, Physics; MS, Aviation Management; PhD, Industrial Management	Regulator2 A&P; Experts on several aircraft models
interviewee8	Male	BS, Aerospace Engineering	Regulator2 A&P & Regulator 4 Aircraft Maintenance Engineer

Table 30 continued

Position and Region	Relevant Experience (Total)	Military	Union
Executive Director at Lobbyist Group in Northeast U.S.	Aviation Legal Battles & Legislation (>30 years)	N	N
Portfolio Trading Manager at Lessor in East China	Airline Management & Aircraft Finance (7 years)	N	N
System Engineer at Airline in East China	Aircraft Maintenance & Quality Assurance (11 years)	N	N
Aviation Safety Inspector (ASI) at Regulator in South China	Aircraft Maintenance, Quality Assurance & Safety Inspection (21 years)	N	N
Office Director at Regulator in Southwest China	Avionics Maintenance, Quality Assurance & Safety Inspection (22 years)	N	N
Vice President of Maintenance at Airline in East China	Avionics Maintenance & Airline Management (26 years)	N	N
Aviation Safety Inspector (ASI) at Regulator in Southwest U.S.	Aircraft Maintenance, Quality Assurance, Airline Management & Safety Inspection (>50 years)	Y (22 years)	Y
Certifying Engineer at Airline in East China	Aircraft Maintenance & Quality Assurance (30 years)	Y (2 years)	Y

Although the first two interviewees are not directly involved with aircraft maintenance activities, the researcher believes their experiences and education are closely related to the issue of aircraft maintenance outsourcing; they provide insights from business and legislation which are important aspects in airline maintenance outsourcing as discussed by the previous literature review.

Interpretation of First Stage Results from Interviewees

Sub-question 2: Based on the first stage research results, the researcher has found better airline financial performance, more maintenance labor assigned to each aircraft within the airlines, and a higher real GDP per capita generally have a positive impact on aviation safety. The percentage of maintenance expense and airline inhouse maintenance labor pay does not affect aviation safety. What are your comments on these results?

The first result was: Air travel is safer when airlines are more profitable.

All the interviewees agreed with this result. Three out of eight interviewees (37.5%) stated that financially sound airlines are more likely to spend more on parts inventory and even renewal of fleets so that they are less likely to experience maintenance problems. Two out of eight interviewees (25%) stated that financially sound airlines will hire good maintenance personnel so that they are good at solving aircraft discrepancies. Two out of eight interviewees (25%) stated that financially sound airlines would have a larger safety budget. Two out of eight interviewees (25%) stated financially sound airlines will pay employees in terms of bonuses or bonds, and there is good morale and culture among employees, which yield positive affects to aviation safety. One out of eight (12.5%) stated that there are contradictions between safety goals and economic goals based on industry experience when airlines are in recession.

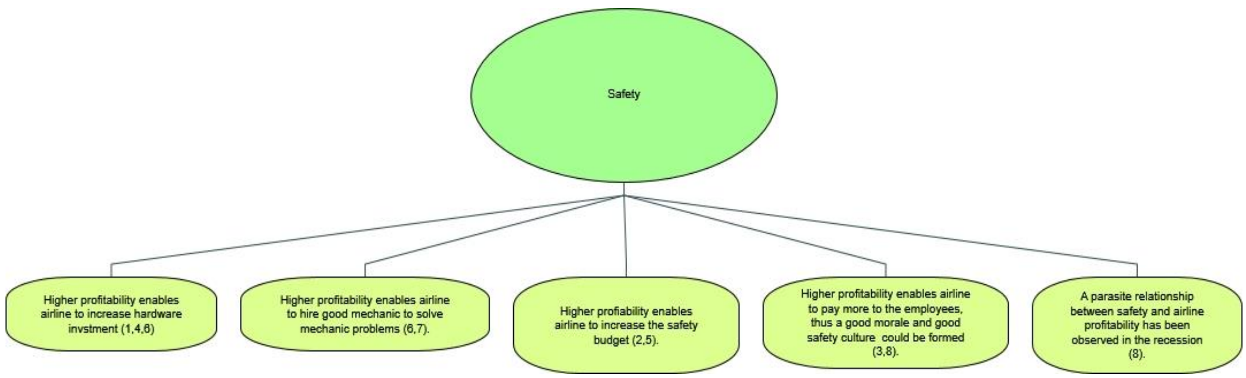

Figure 4. Safety and Profitability

The second result was: Air travel is safer when airlines assign more maintenance labor to each aircraft (MtA).

All the interviewees agreed with this result, but seven out of eight interviewees (87.50%) believe the model needs to include more omitted variables to establish a cause-and-effect or a more convincing relationship. Three out of eight interviewees (37.5%) held that safe airlines often have not only more mechanics but also more experienced and well-trained technical operation teams. One interviewee out of eight interviewees (12.5%) linked the MtA to the airline financial situation, one interviewee (12.5%) found in some periods there were limited aircraft maintenance personnel to handle the work, which could affect aviation safety, and one interviewee (12.5%) found that airline fleet type and operating strategies are confounding variables between MtA and aviation safety. One interviewee (12.5%) considered the general relationship is significant, but it may be non-linear, and he mentioned appropriate allocation of maintenance labor such as using a fatigue risk management tool is more important than seeking a fixed number of maintainers to aircraft ratio. In his country, its regulator used to have a mandate that airlines must have a minimal number of aircraft maintenance personnel for a specific number of aircraft, but the rule has been superseded by minimum work hour/scope requirements in regard to aircraft models.

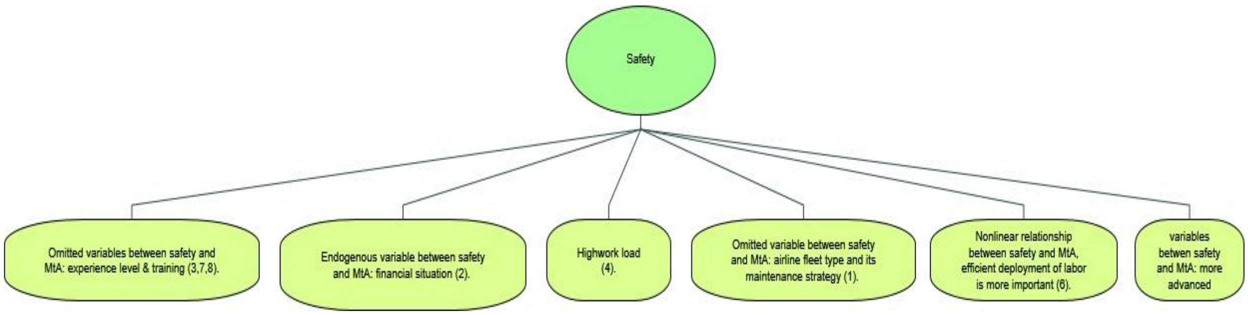

Figure 5. Safety and MtA

The third result was: air travel is safer when the real GDP per capita (RtC) is higher.

All the interviewees agreed with this result. All interviewees (100%) believed a relationship exists between a robust macroeconomy and a good airline financial status. Three out of eight interviewees (37.5%) recalled that aviation accidents occur more often in countries with poor economies. Five of eight interviewees (62.5%) stated RtC is an indicator of productivity which moves in the same pattern with aviation safety. Four out of eight interviewees (50%) thought that under a good economy, airlines or regulators may invest more money on maintenance, training, and safety budgets related to aviation safety. One interviewee (12.5%) added that during a downward-trending economy and poor airline financial performance, airline workers often have low morale due to reduced financial rewards which may affect their work quality and consequently hurt aviation safety.

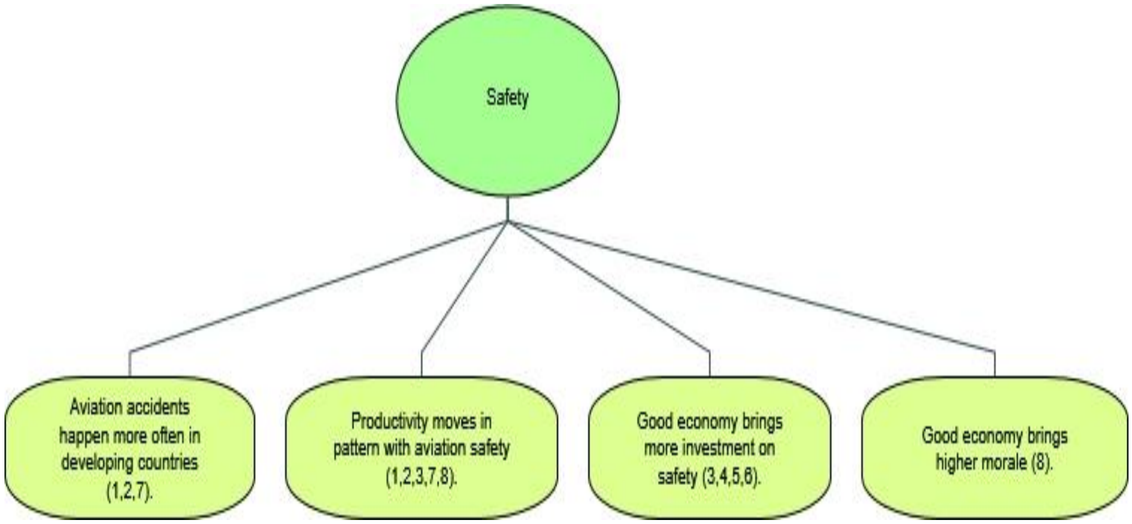

Figure 6. Safety and RtC

The fourth result was: air travel safety is uncorrelated with the percent of maintenance expenses outsourced.

All the interviewees agreed with this result. Three out of eight interviewees (37.5%) stated that many constraints serve to keep outsourced maintenance safe, and one of them is oversight. Five out of eight interviewees (62.5%) stated that more outsourced maintenance work is empirically making airlines safer. Two of them (25%) cited some MRO providers have more experienced labor, and one (12.5%) added the MRO providers also possess more equipment to handle complex tasks. One (12.5%) observed that the MRO providers have better capacity to handle a large volume of workload; he knew one airline where a local regulator even suggested that the airline outsource its extra workload during the Covid-19 pandemic. One (12.5%) summarized that outsourced maintenance could bring extra safety to an airline under two conditions: 1) robust oversight from airlines, regulators, and MRO providers, and 2) transparency of information for the selection of MRO providers based on market adjustment as a practice of industry self-discipline. Three (3.7.5%) observed that outsourced maintenance could affect aviation safety in both ways. Two (25%) considered oversight is a critical factor, while one (12.5%) considered experience level is a critical factor.

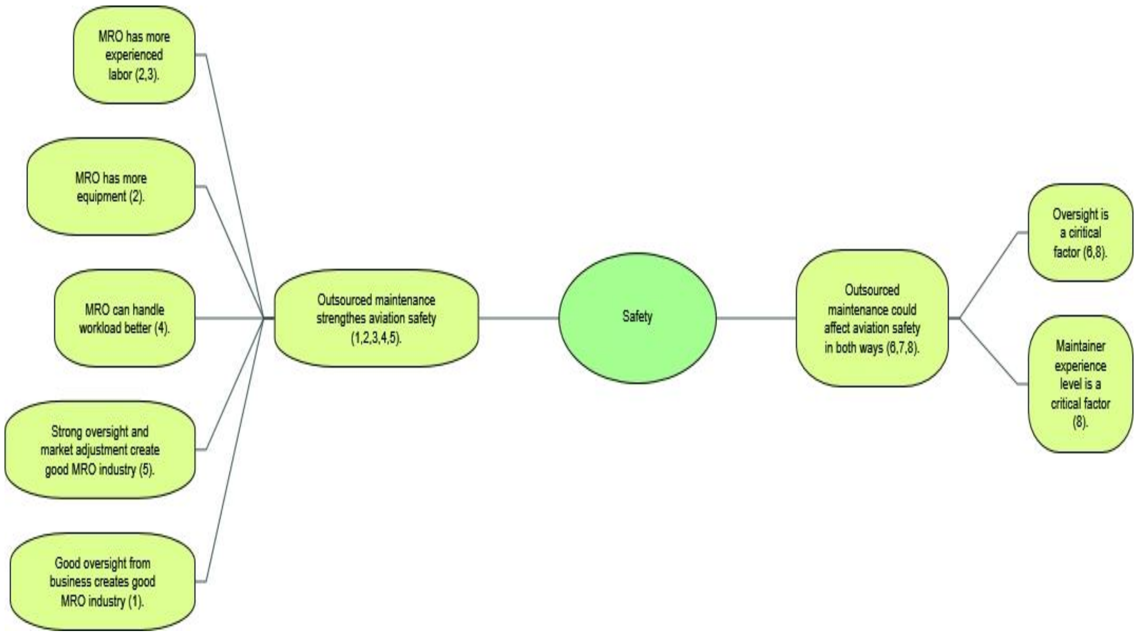

Figure 7. Safety and Omx

The fifth result was: air travel safety is uncorrelated with airline inhouse maintenance pay.

Five out of eight interviewees (62.5%) disagreed with this result. Three out of eight interviewees (37.5%) stated good MxWage could retain experienced and attract qualified employees to keep an airline from bad maintenance practices or low dispatch reliability. One (12.5%) added that besides giving big paycheck to employees, and airlines should pay more to conduct trainings for employees to raise the safety level. One (12.5%) added that the MxWage and airline employee turnover rate is highly influenced by regional effects; in developed regions, MxWage has a hard time catching up with the local price level so that more new employees are apt to leave for a new industry. One (12.5%) observed that prolonged stagnant wages and salaries for maintenance personnel has eroded the morale of the maintenance team and affects aviation safety through the poor work produced by some disgruntled employees at workplace.

Three out of eight interviewees (37.5%) agreed with the result, notably they were not working at airline. Two out of eight interviewees claimed current MxWage could attract appropriate maintenance employees to guarantee minimal work standards so that it has either minimal or negligible negative effects on aviation safety. One (12.5%) initially thought the result was contrary to his instincts, but after consideration he changed his mind based on three reasons:

1) the current MxWage system has attracted the right number of qualified employees to finish maintenance work effectively, 2) airlines have identified other areas for investment in order to ensure aviation safety such as the purchase of new equipment, quick clearing of the minimum equipment list (MEL), compliance with the nonmandatory service bulletin (SB), and 3) the U.S. airline maintenance personnel have passed the human era, so they were dedicated to their work regardless of the amount of their paycheck, and the last reason was more of conjecture than fact.

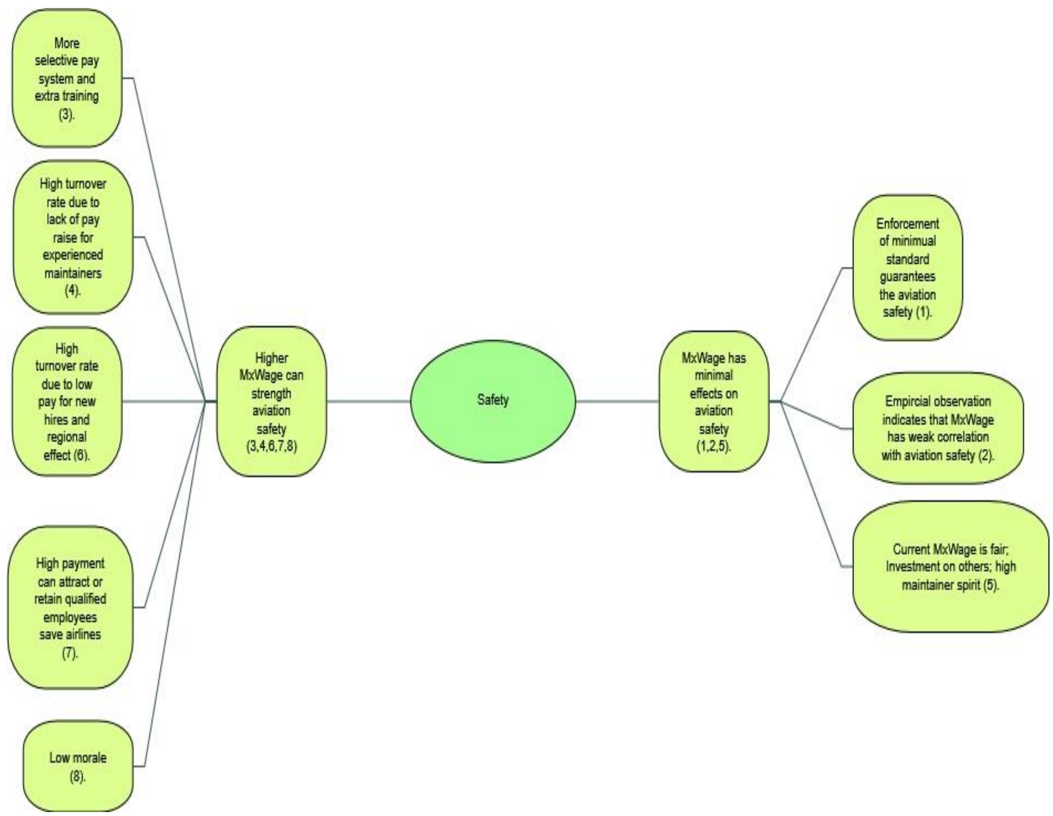

Figure 8. Safety and MxWage

Outsourced Maintenance Factors that Could Jeopardize Aviation Safety

Sub-question 3: What factors have you noticed from the practice of commercial aircraft maintenance outsourcing that might jeopardize aviation safety?

One out of eight interviewees (12.5%) stated that there is no difference in terms of aviation safety between outsourced maintenance and inhouse maintenance and claimed that there are strong oversight systems on airlines and MRO providers from multiple regulatory systems in offshoring maintenance cases, strict adherence to airline internal policies, and trainings for MRO providers. Two out of eight interviewees (25%) stated that outsourced maintenance is dangerous due to a lack of oversight from regulators, two out of eight interviewees (25%) across the borders said regulators have a hard time maintaining a large team of aviation safety inspectors (ASIs) in regard to the huge expansion of the MRO providers and airline fleet growth in recent years. One (12.5%) stressed that current ASIs are unqualified in terms of experience (most from military aviation experience and general aviation experience). They have limited knowledge of transport category aircraft and are deficient middle and upper level leaders with an unsuitable mentality who are mostly retired military officers, who fully embrace the SMS philosophy which is lean management driven and trades cost-reduction for aviation safety degrades. Two interviewees (25%) stated that the airlines have limited oversight over aircraft maintenance outsourcing for the sake of costs and a limited scope of activities and oversight. Three out of eight interviewees stated the MRO providers are likely to fail to comply with maintenance tasks, which is also costly to airline operations. Two interviewees (25%) stated some MRO providers are not capable of working on some tasks as contracted, and one (12.5%) observed this lack of skills often occurs during the first service provided by new MRO providers. One interviewee (12.5%) stated the MRO provider maintenance workers pay less attention to aircraft compared with their counterparts at the airlines. One interviewee (12.5%) stated that the current aviation maintenance industry overemphasized regulatory knowledge instead of technical knowledge and professional knowledge including communication skills and human factors. The same person commented, "…that's the most dangerous thing we can do in aviation is to take our eye off the factory floor, and the hangar floor" (Interviewee X, personal communication, n.d.).

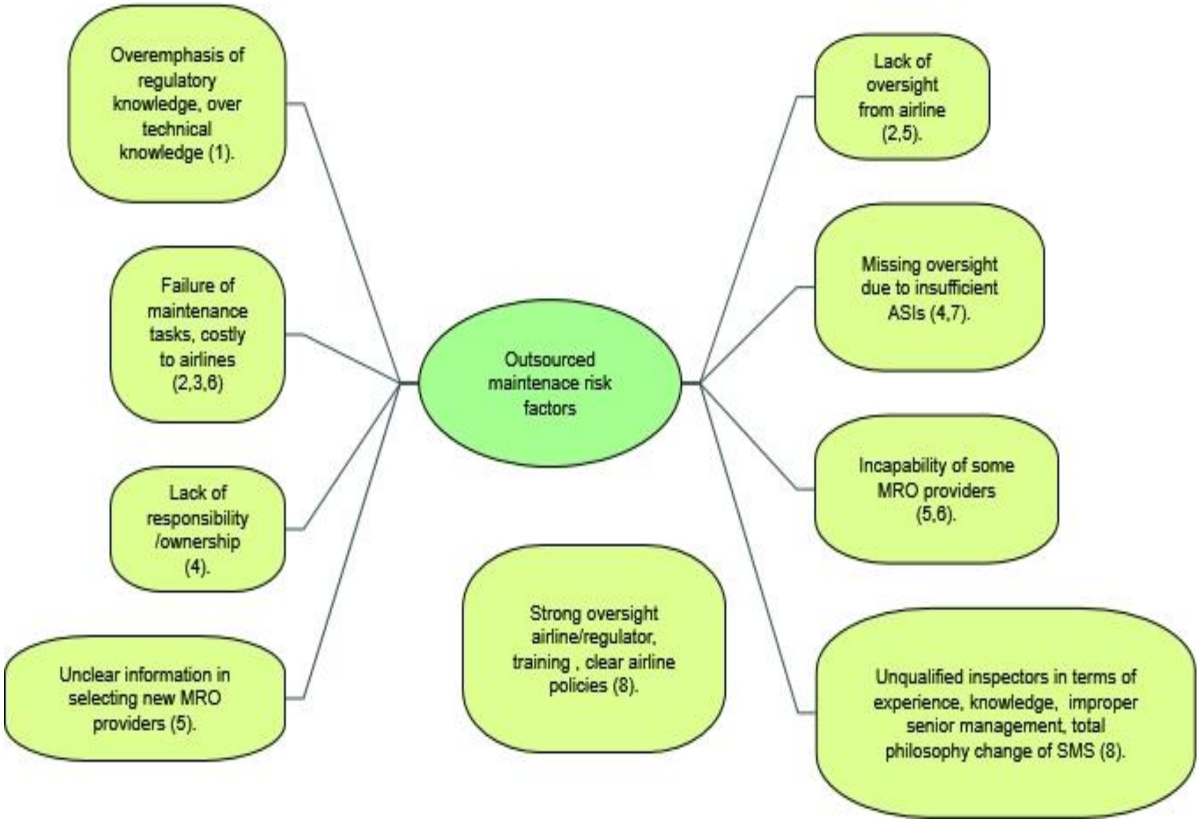

Figure 9. Outsourced Maintenance Risk Factors

Maintenance Quality/Safety Assurance

Sub-question 4: How do airline/organizations assure airline inhouse/outsourcing maintenance quality?

One out of eight interviewees (12.5%) stated that there is no oversight from regulators at all, and he went further to provide the following evidence to support his assertion: the current oversight system is following the SMS which is based on risk-based surveillance with no established baseline. The regulators blindly trust the airlines because of clueless management, unqualified inspectors with limited training, and cost reduction that prioritizes over hands-on and eyes-on surveillance. The person stated in the end, “The regulator in this country is no longer running an effective regulatory agency and it's getting worse daily. I feel like I'm riding an avalanche” (Interviewee X, personal communication, n.d.). One out of eight interviewees (12.5%) stated that his/her organization served as a broker among the airlines, MRO providers, and regulators to facilitate the communication among them. The interviewee kept stressing that everyone needs to understand the differences between regulatory obligations and business obligations. In the interviewee's words, "My organization helps ensure that our eye is always kept on the safety ball is to help the media, Congress and even the industry and most of the agency to understand that it's business that drives the highest degree of safety, not the government" (Interviewee X, personal communication, n.d.). Interestingly, this interviewee held the SMS is just another hassle to disenfranchise mechanics and make extra trouble for the airlines and MRO providers, but current the continuous airworthiness maintenance program is sufficiently adequate. Seven of eight interviewees (87.5%) talked about the annual inspection as a way to assess maintenance quality, but two of eight interviewees (25%) doubted the effectiveness of the annual inspection; one (12.5%) claimed the inspectors in his organization are unqualified and inexperienced, and the other claimed the annual inspection could only catch major unsafe events or concrete evidence. One interviewee (12.5%) stated that financial auditing which focuses on monthly maintenance reserve reports from airlines is a good way to ensure maintenance quality. Lessors also visit airlines or MRO service providers to ensure their assets (aircraft) are in good condition, and by the end of the lease, the redelivery inspections involving heavy check negotiations on things to repair, modify or restore is also a positive way to ensure maintenance quality. In the event of defaults from airlines, lessors will deploy an aircraft repossession team to snatch aircraft and scramble for technical documents to stop the operation of financial insolvent airlines. Regarding new MRO service, three interviewees (37.5%) stated their organization will send a team to audit repair stations; one (12.5%) stated his organization follows 5-5 principles covering five forms of hardware: facility, tooling, equipment, technology, materials, personnel, and five systems: quality system, engineering system, production control system, training system, and safety management system. The other two (25%) stated their organizations mainly examine the level of capability, experience, and compliance of the local and the outsourcing party's regulatory requirements. Two of eight interviewees (25%) mentioned that training for maintenance personnel is an important and necessary way to ensure maintenance quality.

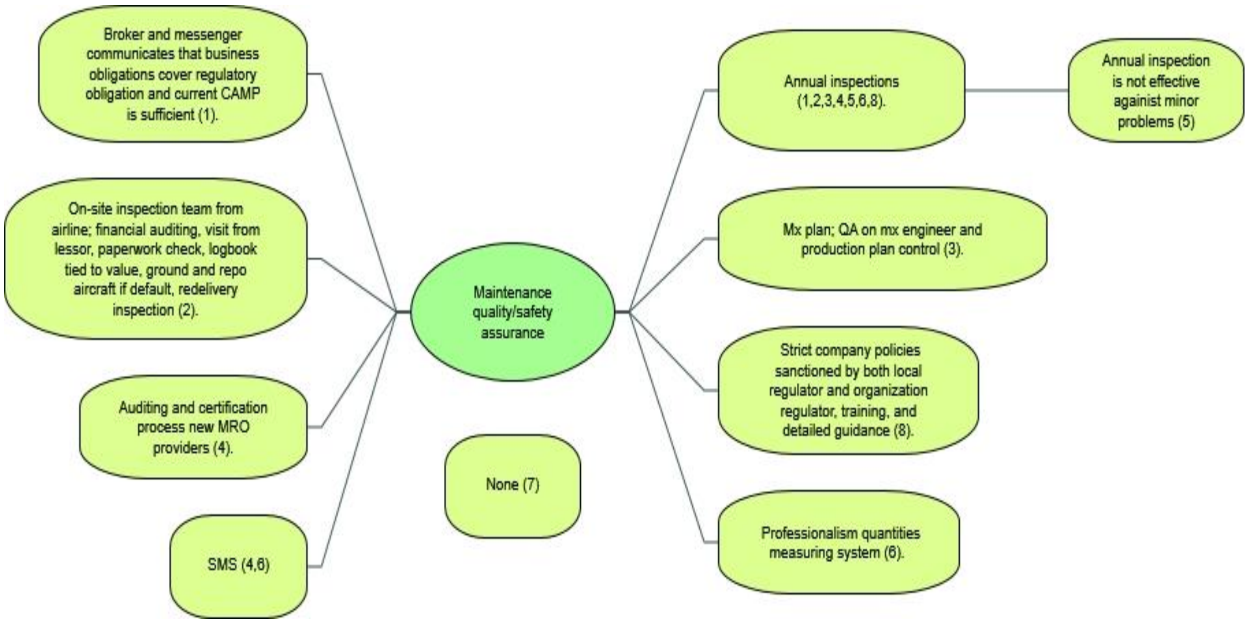

Figure 10. Maintenance Quality/Safety Assurance

Maintenance Outsourcing Decision-making

Sub-question 5: Are you involved with decision-making of outsourcing maintenance and how are you involved?

All the interviewees (100%) stated that they are not directly involved with any maintenance outsourcing decision making process, but they could contribute to decision-making process indirectly. One (12.5%) said s/he could help by organizing meetings for regulators, airlines, media, and legislators and their staff, and the most important message the organization can communicate is to signal that outsourced maintenance only can be properly overseen by business. Five out of eight interviewees (62.5%) stated that they do inspections, and that data collected from inspections can influence the maintenance outsource decision-making process. One (12.5%) said one airline was advised by regulator to outsource the extra heavy workload created by the Covid-19 pandemic. Two interviewees (25%) offered additional insights on what to look for when their organizations are making maintenance outsource decisions; one mentioned three points: cost comparison, experience of the maintenance team of both parties (efficiency), and the airline's internal capacity. The other interviewee explained that s/her organization often choose an MRO service provider based on a bidding process with ranked requirements from high to low such as price based on work duration, former work performance (errors), quality of work, and other items on a score card.

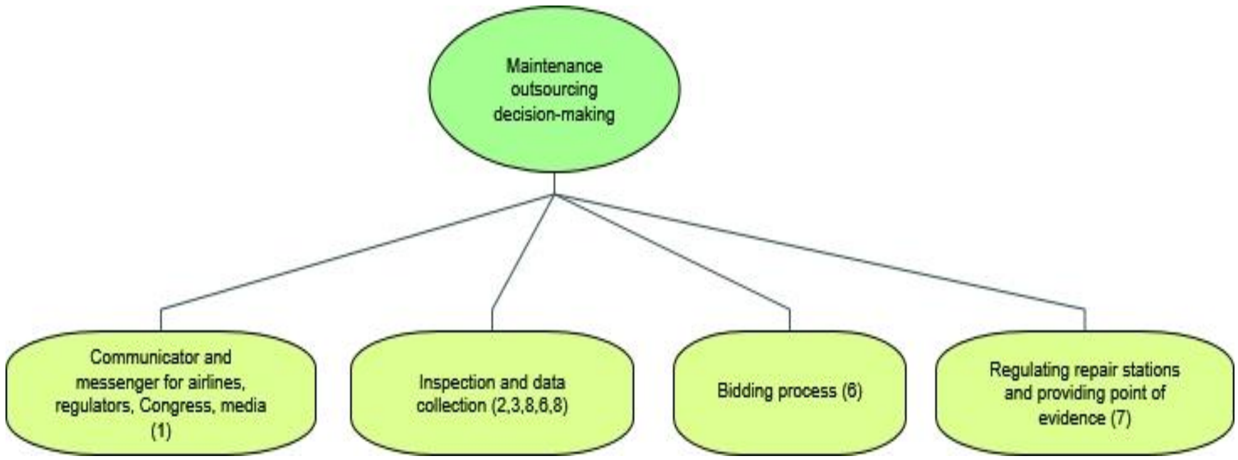

Figure 11. *Maintenance Quality/Safety Assurance*

Further Opinions

Sub-question 6: What would you like to add as a further opinion that was not covered during this interview?

One of eight interviewees (12.5%) did not offer any further opinions for the interview. Two of eight interviewees (25%) expressed that government should not enact regulations to stop airline maintenance outsourcing, and that doing so would not only hurt airline profitability but also jeopardize aviation safety. And one interviewee cited a slogan from his organization to illustrate the intricate and symbiotic relationship between safety and development, "Safety is the basis of development; development is the guarantee of safety" (Interviewee X, personal communication, n.d.). Two of eight interviewees (25%) expressed the limited role that regulators can play in aviation safety; one believed it is a common phenomenon, while the other worried that it is a déjà vu of the organization's history of failure to ensure aviation safety in the mid-90s. One interviewee (12.5%) added that perfect competition among airlines/ MRO service providers with the synergy of the wisdom of society will increase safety to a new level for a positive safety culture. One of eight interviewees (12.5%) observed that by outsourcing heavy maintenance work, airlines have lost a lot of valid data which is useful for reliability analysis and enlargement of the safety margin. One of eight interviewees (12.5%) stated that s/her organization does not have a set model or algorithm to make maintenance outsource decisions including when to outsource/insource, factors analysis, and other analyses, and wanted academia to help create one for the organization. One interviewee (12.5%) observed airline internal politics, regional, and international politics may exert negative influences over maintenance outsourcing, and the FAA A&P mechanic enjoys more freedom in the signing of maintenance paperwork compared with other licensed engineers overseen by regulators around the globe.

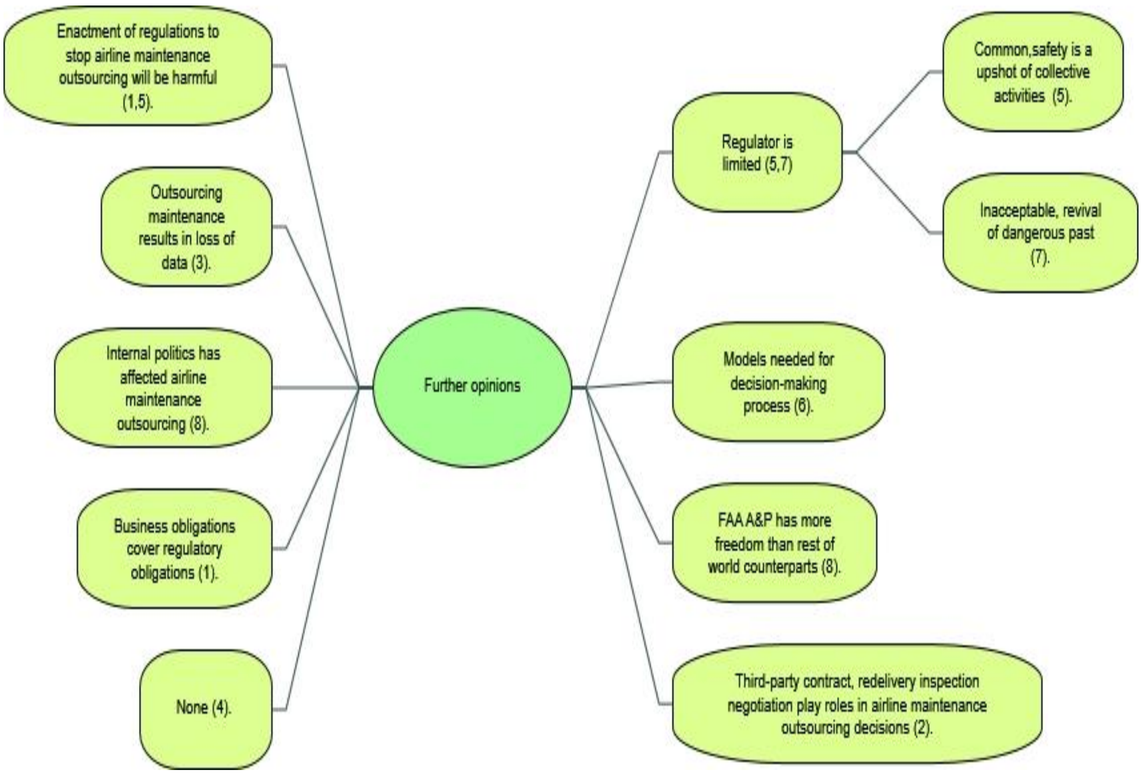

Figure 12. Further Opinions

Summary

In this research, all interviewees agreed that both airline and nation's economic growth have a positive impact on aviation safety because there is more investment on hardware, labor, safety budget, and above all people are generally happier and form a positive work culture during the feast years. There is a positive relationship between airline maintenance labor distribution and aviation safety; however, there are some omitted variables, and one concurred one is aircraft maintainer's experience. There are divergences on the airline inhouse maintenance pay's impact on aviation safety. All the interviewees, who thought there were no impacts, were not employees at the time, and those who thought there were some impacts were airline employees and had previously worked at airlines for a long time.

All the interviewees agreed that airline maintenance outsourcing does not endanger aviation provided it is done properly, and some conditions include sufficient oversight from airlines, regulators, and lessors, and the maintenance receiving party has enough capable work force and equipment to finish the tasks. The research further showed that oversight from both business and government is an important barrier against the accident, but sometimes the oversight was missing due to internal and external organizational factors. Surprisingly, all the interviewees in the U.S. considered the SMS is a bad safety oversight tool and it is ineffective and even detrimental to aviation safety.

No interviewees were directly involved with decision-making process for airline maintenance outsourcing, but they all played indirect roles in the decision-making process. Most of them considered the quality of maintenance work is important in the maintenance-decision making process, but there is no clear way to justify maintenance outsourcing decisions to their knowledge. In the end, the interviewees responses generally reflected their roles in their own organization.

A display of word cloud: word-counting plot of interview transcripts created by the NVivo is provided below:

Figure 13. Word Cloud

CHAPTER 6. CONCLUSIONS

Summary of Study

This study has researched airline maintenance outsourcing and aviation safety from the technology, economics, and political perspective. The central theme distilled from this study is that in the current deregulation era, the airlines in the U.S. and the rest of the world are adopting aircraft maintenance outsourcing as a strategy to save costs—most airlines simply cannot do all the maintenance in-house because of the comparative and absolute advantages. The comparative advantages: MRO providers can often supply lower-than-airline-inhouse prices due to low labor costs and the scale of the economy. The absolute advantages involve unique technical advantages/ asset specificity such as site specificity-close to supporting industry, appealing tax and currency exchange rates offered by offshored governments, physical asset specificity such as spacious hangar space, and human asset specificity-such as pools of specialized workers, and dedicated assets such as-specialized tooling to finish idiosyncratic maintenance tasks such as a paint shop, and non-destructive test (NDT) equipment.

From the first stage quantitative research results, the researcher found no statistically significant relationship between the amount of airline maintenance outsourcing and aviation safety performance, but a statistically significant positive relationship does exist between airline financial performance and aviation safety performance. In addition, and there is statistically significant positive relationship between the national economy and aviation safety performance. These intriguing findings were collectively agreed upon by all the interviewees across the Pacific in the second stage qualitative stage. It reminded us that the top priority for an airline is to make money, but it cannot remain financially solvent without strong safety records. An important by-product of safety provided by the incessant pursuit of safety goals is an increment of operational efficiencies (Cusick et al., 2017; Interviewee X, personal communication, n.d.).

In the democratic society of the U.S., airlines maintenance outsourcing is overtly turning into a contentious political issue on the Congress floor, with stakeholders from unions, airline management, elected politicians, passenger/consumer advocacy groups, and other lobbyists all of whom have stake in the outcomes of safe airline travel. With a fueling from media who “are always consistent with the self-interest of the press" (Coase, 1974, p. 386), this truly turned into "a beautiful sight to behold" (Cowan, 2019).

Suggestions

With these items in mind, the researcher wanted to offer following suggestions:

1) The airlines should try to establish a precise model that determines outsource/insource maintenance.
2) Regulators should enhance their oversight capacity. In light of the current limited budget, they might consider adopting an activities-based accounting, that charges airline/MRO service providers based on inspection scopes and frequencies. With more funding available for the regulators, the regulators could hire more experienced and qualified inspectors.
3) The accident investigation body should add extra codes to classify the sources of maintenance errors, stating whether they are caused by the actions of inhouse maintenance, outsourced maintenance, or offshored maintenance.
4) The government should not pass radical legislation that coercively changes the supply-and-demand market relationship of outsourced maintenance to favor special interest groups.

Future Study

Instead of asking what amount of airline maintenance work should be outsourced, safety and business-conscious people need to ask these two questions for the future study:

Which MRO providers should airlines choose to prevent high consequence failures from happening while save the most of money and time?

This job may be outsourced to independent consultants or academia because they are good at creating theoretical but not practical models because of little empirical data available to them, and airlines could provide them with empirical data to demystify existing think habit and gain useful advice from the academia (Coase, 1994).

How can an efficient oversight system be set up to catch and correct faulty actions and wrong-doers if an accident or an incident takes place?

The current oversight system and past oversight systems have received many criticisms from the industry and regulator. The future oversight system designers need to study these criticisms and come up with practical ways to improve effectiveness of it.

APPENDIX A. SEMI-STRUCTURED INTERVIEW QUESTIONS

Sub-question 1: What is your background (demographic, the organizations/companies you have served/ are serving, technical skills, experience, and whether they are affiliated with aircraft mechanic labor union)?

Sub-question 2: Based on the first stage research results, the researcher has found better airline financial performance, more maintenance labor assigned on each aircraft within the airlines, and higher real GDP per capita generally have positive impacts on the aviation safety. And the percentage of maintenance expense and airline inhouse maintenance labor pay does not affect aviation safety. What are your comments on these results?

Sub-question 3: What factors have you noticed from the practice of commercial aircraft maintenance outsource might jeopardize aviation safety?

Sub-question 4: How does the airline/organization assure airline inhouse/outsourcing maintenance quality?

Sub-question 5: Are you involved with decision-making of outsourcing maintenance and how are you involved?

Sub-question 6: What would you like to add as a further opinion that was not covered during this interview?

APPENDIX B. CONSENT FORM

Airline Maintenance Outsource Strategy and Aviation Safety
Ph.D. candidate Linfeng Jin
Prof. Chien-tsung Lu, Ph.D.
Aviation and Transportation Technology
Purdue University

Key Information

Please take time to review this information carefully. This is a research study. Your participation in this study is voluntary which means that you may choose not to participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to take part in the study, you will be asked to sign this form, be sure you understand what you will do and any possible risks or benefits.

The study name is "Airline Maintenance Outsource Strategy and Aviation Safety" The study is in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Technology. The study started in January 2020 and will end in July 2021. The study is to explore the effects of passenger airline maintenance outsource on aviation safety of passenger airlines via the explanatory sequential mixed methods research. The first stage of the research was a quantitative research using a panel data analysis to explore the statistical relationships between the variables related to the airline maintenance identified and the variation of safety performance metrics for the FAA major Part 121 passenger air carriers between 1995 and 2019.

In the first stage research, the researcher proposed several independent variables might affect the aviation safety of the airlines measured as the dependent variables include accident rate and incident rate. The first dependent variable is accident rate (**AcciRate**) which is equal to accident count divided by total aircraft block hours for a specific airline each year, and the second dependent variable (**InciRate**) is incident rate which is equal to incident count divided by total aircraft block hours for a specific airline each year. The independent variables are listed as the following percent of maintenance expenses outsourced (**Omx**), airline inhouse maintenance personnel per aircraft (**MtA**), real average annual wages and salaries - inhouse maintenance personnel (**MxWage**), airline profitability adjusted for inflation (**Profitability**), and real GDP per capita (**RtC**).

In summary, the researcher concluded the first stage research with the following results listed by the order of magnitude of impact on aviation safety:

- Air travel is safer when airlines are more profitable.
- Air travel is safer when airlines assign more maintenance labor on each aircraft.
- Air traveler is safer when real GDP per capita is higher.
- Air travel safety is uncorrelated with the percent of maintenance expenses outsourced.
- Air travel safety is uncorrelated with the airline inhouse maintenance pay.

The second stage qualitative research intended to ask the interviewees to refine and explain the statistical results of the first quantitative research effect of passenger airline aircraft maintenance outsourcing on the aviation safety of passenger airline aircraft, construct the recommendations for the improvements of aviation safety and airline maintenance, and provide guidance for the future research.

<u>What is the purpose of this study?</u>

You identified by the researchers might serve an important role in explaining the results and offering feedbacks based on your educational background, technical competencies, and industrial experiences. We would like to enroll saturation amount of people in this study. The sample size will be limited to a saturation point with an appearance of "information redundancy, not a statistical confidence level" (Lincoln & Guba, 1985, p. 202).

<u>What will I do if I choose to be in this study?</u>

You will answer the following questions.
Sub-question 1: What is your background (demographic, the organizations/companies you have served/ are serving, technical skills, experience, and whether they are affiliated with aircraft mechanic labor union)?
Sub-question 2: Based on the first stage research results, the researcher has found better airline financial performance, more maintenance labor assigned on each aircraft within the airlines, and higher real GDP per capita generally have positive impacts on the aviation safety. And the percentage of maintenance expense outsourced and airline inhouse maintenance labor pay do not affect aviation safety. What are your comments on these results?
Sub-question 3: What factors have you noticed from the practice of commercial aircraft maintenance outsource might jeopardize aviation safety?
Sub-question 4: How does the airline/organization assure airline inhouse/outsourcing maintenance quality?
Sub-question 5: Are you involved with decision-making of outsourcing maintenance and how are you involved?
Sub-question 6: What would you like to add as a further opinion that was not covered during this interview?
All your answer will be recorded, and the interview scripts produced by the researcher will be sent back to you for your verification and clarification. The process is not experimental, all the data collected will be de-identified, saved in a secure location: Dr. Lu office's computer confidentially and will be destroyed in one year after the dissertation is published.

<u>How long will I be in the study?</u>

The interview with you plan to take less than 25 minutes, and normally one interview shall be expected. And transcript reading and feedback may take up to as much time as you wish. (We estimate about 30 minutes).

What are the possible risks or discomforts?

The risk level for you to take the interview will be minimal since all the interviews will take place using private password-protected communication applications, the interview audio recording will be saved in a secure location, the key identification information will be de-identified, and transcripts and feedbacks will be only exchanged through emails. So, it is important to maintain the confidentiality. Breach of confidentiality is always a risk with data, but we (the researchers and interviewees) will take precautions to minimize this risk as described in the confidentiality section.

Are there any potential benefits?

There is no direct benefit from this study.

This section provides more information about the study

Will information about me and my participation be kept confidential?

The project's research records may be reviewed by the study sponsor/funding agency, Food and Drug Administration (if FDA regulated), US DHHS Office for Human Research Protections, and by departments at Purdue University responsible for regulatory and research oversight.

There are no confirmed funding sources currently. The confidentiality of identifying participant will be maintained in a way that only the researcher and his advisor or committee member who introduced interviewee know. Only the researcher and his committee will have access to the confidential information entailed in the interview audio recordings, transcripts, and email communications for this study purpose. All the data collected will be de-identified, saved in a secure location: Dr. Lu office's computer confidentially and will be destroyed in three years after the dissertation is published. The identification data will be coded using the code key, and the code key will be saved in Dr. Lu office's computer confidentially. The data will be used for future use research with the permission from the interviewees.

What are my rights if I take part in this study?

You do not have to participate in this research project. If you agree to participate, you may withdraw your participation at any time without penalty. You may withdraw from the research by telling the interviewer if it is in the interview process and writing an email to the researcher (jin223@purdue) and the researcher's advisor (ctlu@purdue.edu) if it takes place after interview. The researcher will destroy the data collected from you after the withdrawal. The deadline for withdraw from the research is date (estimated early July 2021) when the researcher submittal of the dissertation draft to the committee for the purpose of dissertation defense. The researcher will terminate the research process when there is predictable significant harm or damage to the researcher and research participants (such as the ringing of fire alarm in the researcher's office).

Who can I contact if I have questions about the study?

If you have questions, comments, or concerns about this research project, you can talk to one of the researchers. Please contact Prof. Chien-tsung Lu via the following ways:

Email: ctlu@purdue.edu
Phone: 765-494-6387
TERM 218
School of Aviation and Transportation Technology
Purdue University
West Lafayette, Indiana 47907
To report anonymously via Purdue's Hotline, see www.purdue.edu/hotline

If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:

Human Research Protection Program - Purdue University
Ernest C. Young Hall, Room 1032
155 S. Grant St.
West Lafayette, IN 47907-2114

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

Alternatively, I will reply to the researcher request email containing following words:

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above.

____ ________________________
Participant's Signature Date

____
Participant's Name

____ ________________________
Researcher's Signature Date

REFERENCES

A review of aviation safety in the United States: Hearing before the Subcommittee on Aviation of the Committee on Transportation and Infrastructure, House of Representatives, 112th Congress, 2nd session. (2012). U.S. Government Printing Office.

Abel, A. B., Bernanke, B., & Croushore, D. (2016). Macroeconomics. Pearson Education.

Ackert, S. P. (2010). Basics of aircraft maintenance programs for financiers. http://www.aircraftmonitor.com/uploads/1/5/9/9/15993320/basics_of_aircraft_maintenance_programs_for_financiers___v1.pdf

Actions needed to improve safety oversight and security at aircraft repair stations (CC-2010–005; p. 12). (2009).

Adrangi, B., Chow, G., & Raffiee, K. (1997). Airline deregulation, safety, and profitability in the U.S. Transportation Journal, 36(4), 44–52.

Aeronautical Repair Station Association. (n.d.). Aeronautical Repair Station Association: Overview | LinkedIn. Retrieved June 28, 2020, from https://www.linkedin.com/company/aeronautical-repair-station-association/

Aeronautical Repair Station Association. (2019, June 11). Unions Organize: Prepare for Anti-Repair Station Legislative Blitz – ARSA. http://arsa.org/foreign-entanglements/

Airbus Customer Service. (2018). Airline maintenance inspection intervals. Author.

Aircraft maintenance outsourcing summit. (2019, June 4). https://www.youtube.com/watch?v=Ra9jY-ndF44&list=LL&index=1

aiReform. (2013, November 22). FAA History: 1985. Aviation Impact Reform. http://aireform.com/resources/faa-history-pages/faa-history-1985/

Airlines for America. (2018, March 14). Airlines for America forecasts 151 million flyers for record-high spring travel season. https://www.airlines.org/news/airlines-for-america-forecasts-151-million-flyers-for-record-high-spring-travel-season/

Akerlof, G. A. (1982). Labor contracts as partial gift exchange. The Quarterly Journal of Economics, 97(4), 543–569. https://doi.org/10.2307/1885099

Albakkoush, S., Pagone, E., & Salonitis, K. (2020). Scheduling challenges within maintenance repair and overhaul operations in the civil aviation sector. 9th International Conference on Through-life Engineering Service, Cranfield, UK.

Al-kaabi, H., Potter, A., & Naim, M. (2007). An outsourcing decision model for airlines' MRO activities. Journal of Quality in Maintenance Engineering, 13(3), 217–227. https://doi.org/10.1108/13552510710780258

Arnold, K. (2019, October 27). After a year of labor unrest, American and Southwest fall behind in another round of contract negotiations. Dallas News. https://www.dallasnews.com/business/airlines/2019/10/27/after-a-year-of-labor-unrest-american-and-southwest-fall-behind-in-another-round-of-contract-negotiations/

Asadi, H., Yu, D., & Mott, J. H. (2019). Risk factors for musculoskeletal injuries in airline maintenance, repair & overhaul. International Journal of Industrial Ergonomics, 70, 107–115. https://doi.org/10.1016/j.ergon.2019.01.008

Bağan, H., & Gerede, E. (2017). A qualitative study on the exploration of safety hazards related to the outsourcing of aircraft maintenance. Business & Management Studies: An International Journal; Bursa, 5(3), 654–683. http://dx.doi.org.ezproxy.lib.purdue.edu/10.15295/bmij.v5i3.146

Bağan, H., & Gerede, E. (2019). Use of a nominal group technique in the exploration of safety hazards arising from the outsourcing of aircraft maintenance. Safety Science, 118, 795–804. https://doi.org/10.1016/j.ssci.2019.06.012

Ballesteros, J. S. (2007). Improving air safety through organizational learning: Consequences of a technology-led model (1 ed., pp. 1–180). Ashgate Publishing Ltd. https://doi.org/10.4324/9781315588032

Baltagi, B. (2005). Econometric analysis of panel data (3rd ed.). John Wiley & Sons.

Barnett, A. (2007). Measure for measure. A statistician offers his perception of the relative usefulness of different ways of measuring aviation safety. Flight Safety Foundation. https://flightsafety.org/wp-content/uploads/2016/12/asw_nov07_p48-52.pdf

Barnett, A., & Wang, A. (2000). Passenger-mortality risk estimates provide perspectives about airline safety. Flight Safety Digest, 19(4), 1–13.

Batuwangala, E., Silva, J., & Wild, G. (2018). The regulatory framework for safety management systems in airworthiness organisations. Aerospace, 5(4), 117. https://doi.org/10.3390/aerospace5040117

Bazargan, M. (2016). Airline maintenance strategies – in-house vs. Outsourced – an optimization approach. Journal of Quality in Maintenance Engineering; Bradford, 22(2), 114–129. http://dx.doi.org.ezproxy.lib.purdue.edu/10.1108/JQME-08-2015-0038

Belobaba, P., Odoni, A. R., Barnhart, C., & Bamber, G. (2016). The global airline industry (2nd ed.). Wiley.

Bennett, R. D., & Craun, J. M. (1996). Low-cost airline service revolution. the U.S. Department of Transportation. https://trid.trb.org/View/471932

Bibel, G. (2008). Beyond the black box: The forensics of airplane crashes. Johns Hopkins University Press.

Bogoch, I. I., Creatore, M. I., Cetron, M. S., Brownstein, J. S., Pesik, N., Miniota, J., Tam, T., Hu, W., Nicolucci, A., Ahmed, S., Yoon, J. W., Berry, I., Hay, S. I., Anema, A., Tatem, A. J., Macfadden, D., German, M., & Khan, K. (2015). Assessment of the potential for international dissemination of Ebola virus via commercial air travel during the 2014 west African outbreak. The Lancet, 385(9962), 29–35. https://doi.org/10.1016/S0140-6736(14)61828-6

Borenstein, S., & Zimmerman, M. (1988). Market incentives for safe commercial airline operation. The American Economic Review, 78(5), 913–935. https://doi.org/10.2307/1807157

Bourjade, S., Huc, R., & Muller-Vibes, C. (2017). Leasing and profitability: Empirical evidence from the airline industry. Transportation Research Part A: Policy and Practice, 97, 30–46. https://doi.org/10.1016/j.tra.2017.01.001

Bowen, B., Headley, D. E., & Lu, C.-T. (2003). Benchmarking airline service performance: A reference point for airline and government evaluation. Public Works Management & Policy, 7(3), 188–204. https://doi.org/10.1177/1087724X02238855

Bowen, B., & Lu, C.-T. (2000). Advocating the implementation of an airline safety information system. Public Works Management & Policy, 5(2), 91–96. https://doi.org/10.1177/1087724X0052001

The oversight of foreign aviation repair stations, The Senate (2007) (testimony of Tom Brantley).

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. The Review of Economic Studies, 47(1), 239–253. https://doi.org/10.2307/2297111

Britton, T. (2016, April 13). What is FAA safety assurance system (SAS)? http://aviationsafetyblog.asms-pro.com/blog/what-is-faa-sas

Brons, M., Pels, E., Nijkamp, P., & Rietveld, P. (2002). Price elasticities of demand for passenger air travel: A meta-analysis. Journal of Air Transport Management, 8(3), 165–175. https://doi.org/10.1016/S0969-6997(01)00050-3

Bruce, P. J., Gao, Y., & King, J. M. C. (2018). Airline operations: A practical guide (1st ed.). Routledge. https://www.taylorfrancis.com/books/9781315566450

Bureau of Transportation Statistics. (2020, April 13). Annual U.S. domestic average itinerary fare in current and constant dollars. https://www.bts.gov/content/annual-us-domestic-average-itinerary-fare-current-and-constant-dollars

Business Travel Coalition. (2008). Aircraft maintenance outsourcing issue. Author. http://businesstravelcoalition.com/campaigns/outsourcing/outsourcing_issue_analysis.pdf

Butler, E. (2012). The condensed wealth of nations. The Adam Smith Institute.

Callaci, B. (2020). Fissuring in flight: Consolidation and outsourcing in the us domestic airline industry, 1997-2018 (p. 64). Communications Workers of America. https://cwa-union.org/sites/default/files/20200108-fissuring-in-flight.pdf

Airline Deregulation Act, Pub. L. No. 95–504 (1978). https://www.congress.gov/bill/95th-congress/senate-bill/02493

Card, D. (1996). Deregulation and labor earnings in the airline industry (NBER Working Paper 5687; NBER Working Paper, p. 5687). National Bureau of Economic Research. https://search.proquest.com/docview/1690239305/86E6C16092C54610PQ/1

Carlisle, L. A. (2001). The FAA v. the NTSB: Now that Congress has addressed the Federal Aviation Administration's "dual mandate," has the FAA begun living up to its amended propose of making air travel safer, or is the National Transportation Safety Board still doing its job alone? Journal of Air Law and Commerce, 66(2), `788.

CBS 2 News Morning. (2019, June 14). Supervisor goes on tirade after american airlines mechanic writes up safety concern. https://chicago.cbslocal.com/video/4104922-supervisor-goes-on-tirade-after-american-airlines-mechanic-writes-up-safety-concern/

Center for Responsive Politics. (2020a, December 31). Rep. John Garamendi—Campaign Finance Summary. OpenSecrets. https://www.opensecrets.org/members-of-congress/john-garamendi/summary?cid=N00030856&cycle=2020

Center for Responsive Politics. (2020b, December 31). Rep. Peter DeFazio—Campaign Finance Summary. OpenSecrets. https://www.opensecrets.org/members-of-congress/peter-defazio/summary?cid=N00007781&cycle=2020

Chaison, G. (2007). Airline negotiations and the new concessionary bargaining. Journal of Labor Research, 28(4), 642–657. https://doi.org/10.1007/s12122-007-9011-4

Chang, Y.-H., & Wang, Y.-C. (2010). Significant human risk factors in aircraft maintenance technicians. Safety Science, 48(1), 54–62. https://doi.org/10.1016/j.ssci.2009.05.004

Chow, G. (1960). Tests of equality between sets of coefficients in two linear regressions. Econometrica (Pre-1986), 28(3), 591–605. https://doi.org/10.2307/1910133

Coase, R. (1937). The nature of the firm. Economica, 4(16), 386–405. JSTOR. https://doi.org/10.2307/2626876

Coase, R. (1974). The market for goods and the market for ideas. The American Economic Review, 64(2), 384–391.

Coase, R. (1994). Essays on economics and economists. University of Chicago Press.

Connors, J. (2000). Engines of Pratt and Whitney: A technical history (N. Allen, Ed.). American Institute of Aeronautics and Astronautics. http://ebookcentral.proquest.com/lib/purdue/detail.action?docID=3111680

Cooper, T., Regan, I., Porter, C., & Precourt, C. (2019). Global fleet & MRO market forecast commentary 2019-2029 (pp. 1–46). Oliver Wyman. https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2019/January/global-fleet-mro-market-forecast-commentary-2019-2029.pdf

Cowan, R. (2019, June 19). U.S. House Speaker Pelosi backs bill aimed at protecting Hong Kong rights. Reuters. https://www.reuters.com/article/us-hongkong-pelosi-idUSKCN1TK2BP

Creswell, J. W. (2018). Designing and conducting mixed methods research (3rd ed.). SAGE.

Croissant, Y., & Millo, G. (2008). Panel data econometrics in R: The plm package. Journal of Statistical Software, 27(1), 1–43. https://doi.org/10.18637/jss.v027.i02

Cusick, S. K., Cortes, A. I., & Rodrigues, C. C. (2017). Commercial aviation safety (6th ed.). McGraw-Hill Education. http://ebookcentral.proquest.com/lib/purdue/detail.action?docID=6403970

Czepiel, E. (2003). Practices and perspectives in outsourcing aircraft maintenance (DOT/FAA/AR-02/122). National Technical Information Service. http://www.dtic.mil/docs/citations/ADA413641

DeFazio, P. A. (2019, November 15). Chair Defazio introduces legislation to strengthen aviation safety standards at foreign repair stations. Congressman Peter DeFazio. https://defazio.house.gov/media-center/press-releases/chair-defazio-introduces-legislation-to-strengthen-aviation-safety

DeFazio, P. A. (2020, July 29). H.R.5119 - 116th Congress (2019-2020): Safe Aircraft Maintenance Standards Act (2019/2020) [Legislation]. https://www.congress.gov/bill/116th-congress/house-bill/5119

Denis, M. (2012). MRO networks. Aircraft IT MRO EJournal, Summer. https://www.aircraftit.com/articles/mro-networks/?area=mro

Department for Business, Innovation and Skills. (2016). UK aerospace maintenance, repair, overhaul & logistics industry analysis (BIS Research Paper Number 275, pp. 1–86). Author. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/502588/bis-16-132-uk-mrol-analysis.pdf

Dillingham, G. L. (2014). Aviation workforce: Current and future availability of aviation engineering and maintenance professionals. In United States Government Accountability Office, Feb 2014, ii+47 pp. (GAO-14-237; pp. 1–52). United States Government Accountability Office. http://search.proquest.com/docview/1622288770/2CCA190D57B9466DPQ/1

Edelberg, W. (2019). The effects of the partial shutdown ending in January 2019 (pp. 1–12). Congressional Budget Office.

Edwards, E. (1977). Automation in civil transport aircraft. Applied Ergonomics, 8(4), 194–198. https://doi.org/10.1016/0003-6870(77)90163-6

European Union Aviation Safety Agency. (2019). Annual safety review 2019. Author. https://www.easa.europa.eu/sites/default/files/dfu/Annual%20Safety%20Review%202019.pdf

Federal Aviation Administration. (2015). Safety management systems for aviation service providers (Advisory Circular AC: 120-92B).

Federal Aviation Administration. (2016a, June 27). What we do [Template]. https://www.faa.gov/about/mission/activities/

Federal Aviation Administration. (2016b, July 14). Safety management system – basis [Template]. https://www.faa.gov/about/initiatives/sms/explained/basis/

Federal Aviation Administration. (2016c). The economic impact of civil aviation on the U.S. economy 2016 (p. 36). Author. https://www.faa.gov/air_traffic/publications/media/2016-economic-impact-report_FINAL.pdf

Federal Aviation Administration. (2017). Safety risk management policy (Order 8040.B). Federal Register. https://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.current/documentNumber/8040.4

Federal Aviation Administration. (2018). Lessons Learned. https://lessonslearned.faa.gov/ll_main.cfm?TabID=1&LLID=28&LLTypeID=2

Federal Aviation Administration. (2020). The economic impact report of civil aviation on the U.S. economy 2020. Author.

Fischer, J. W., Elias, B., & Kirk, R. S. (2008). U.S. airline industry: Issues and role of congress (No. RL34467). U.S. Congress. https://www.everycrsreport.com/files/20080729_RL34467_413b45a3adb8610dc5c66b4f1c215771be4358c4.pdf

Flannery, J. A. (2001). Safety Culture and its measurement in aviation. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.200.9052&rep=rep1&type=pdf

Flouris, T. G., & Oswald, S. L. (2012). Designing and executing strategy in aviation management. Ashgate Publishing Ltd.

Foreign Repair Stations: The Critical Need for their Existence and the Global Nature of the Aviation Maintenance Industry. (2007). the Aeronautical Repair Station Association. http://arsa.org/wp-content/uploads/2012/09/ARSATestimony-6-20-07.pdf

Garamendi, J. (2019, September 18). H.R.4374 - 116th Congress (2019-2020): Aircraft Maintenance Outsourcing Disclosure Act of 2019 (2019/2020) [Webpage]. https://www.congress.gov/bill/116th-congress/house-bill/4374

General Accounting Office. (1997). FAA oversight of repair stations needs improvement. http://www.dtic.mil/docs/citations/ADA331829

Ghobrial, A. (2005). Outsourcing in the airline industry: Policy implications. Journal of Transportation Law, Logistics, and Policy, 72(4), 457–473.

Gittell, J. H., Von Nordenflycht, A., & Kochan, T. A. (2004). Mutual gains or zero sum? Labor relations and firm performance in the airline industry. Industrial & Labor Relations Review, 57(2), 163–180. https://doi.org/10.1177/001979390405700201

Given, L. M. (Ed.). (2008). The SAGE encyclopedia of qualitative research methods. SAGE. http://knowledge.sagepub.com/view/research/SAGE.xml

Gnehm, E. (2013). Annex 19: A key amendment to the Convention. ICAO Journal, 68(05), 60–63.

Goetz, A. R., & Vowles, T. M. (2009). The good, the bad, and the ugly: 30 years of US airline deregulation. Journal of Transport Geography, 17(4), 251–263. https://doi.org/10.1016/j.jtrangeo.2009.02.012

Government Accountability Office. (n.d.). Aviation safety: System safety approach needs further integration into FAA’s oversight of airlines. Retrieved June 2, 2021, from https://www.gao.gov/products/gao-05-726

Government Accountability Office. (1997). Aviation safety: FAA oversight of repair stations needs improvement (GAO/RCED 98-21). http://www.dtic.mil/docs/citations/ADA331829

Government Accountability Office. (2003a). Aviation safety: FAA needs to update curriculum and certification requirements for aviation mechanics [GAO-03-317]. Author. https://www.gao.gov/assets/240/237550.pdf

Government Accountability Office. (2003b). Airline labor relations: Information on trends and impact of labor actions (GAO-03-652). Author. https://www.gao.gov/assets/240/238591.pdf

Government Accountability Office. (2004). Commercial aviation legacy airlines must further reduce costs to restore profitability: Report to congressional committees. (GAO-04-836). Author. https://www.gao.gov/products/GAO-04-836

Government Accountability Office. (2005). Aviation safety: System safety approach needs further integration into FAA's oversight of airlines (GAO-05-726). Author. https://www.gao.gov/assets/250/247956.pdf

Government Accountability Office. (2010). Aviation safety: Certification and approval processes are generally viewed as working well, but better evaluative information needed to improve efficiency (GAO-11-14). Author. https://www.gao.gov/assets/320/311045.pdf

Government Accountability Office. (2012). Aviation safety: Additional FAA efforts could enhance safety risk management (GAO-12-898). Author. https://www.gao.gov/assets/650/648110.pdf

Government Accountability Office. (2016). Aviation safety: FAA's risk-based oversight for repair stations could benefit from additional airline data and performance metrics (GAO-16-679). Author. https://www.gao.gov/assets/680/678735.pdf

Government Accountability Office. (2020). Aviation maintenance: Additional coordination and data could advance FAA efforts to promote a robust, diverse workforce (GAO-20-206). Author. https://www.gao.gov/assets/710/704382.pdf

Graham, D., Kaplan, D., & Sibley, D. (1983). Efficiency and Competition in the Airline Industry. Bell Journal of Economics, 14(1), 118–138. https://doi.org/10.2307/3003541

Grant, R. G. (2002). Flight: 100 years of aviation (1st American ed.). DK Pub; in association with the Smithsonian Institution's National Air and Space Museum.

Greer, M. (2009). Is it the labor unions' fault? Dissecting the causes of the impaired technical efficiencies of the legacy carriers in the United States. Transportation Research Part A: Policy and Practice, 43(9), 779–789. https://doi.org/10.1016/j.tra.2009.07.007

Gubrium, J. F., Holstein, J. A., Marvasti, A. B., & McKinney, K. D. (2012). The SAGE handbook of interview research: The complexity of the craft (2nd ed.). SAGE Publications.

Hamermesh, D. S. (2011). Beauty pays: Why attractive people are more successful. Princeton University Press.

Hamilton, J. S., & Nilsson, S. (2015). Practical aviation & aerospace law (6th ed.). Aviation Supplies & Academics, Inc. http://ebookcentral.proquest.com/lib/purdue/detail.action?docID=5631312

Hansen, M. M., McAndrews, C., & Berkeley, E. (2008). History of aviation safety oversight in the United States (DOT/FAA/AR-08/39). Office of Aviation Research and Development, Federal Aviation Administration.

Hausman, J. A. (1978). Specification tests in econometrics. Econometrica, 46(6), 1251–1271. JSTOR. https://doi.org/10.2307/1913827

Hawkins, F. H. (1993). Human factors in flight. Gower Technical Press.

Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. Evidence-Based Nursing, 18(3), 66–67. https://doi.org/10.1136/eb-2015-102129

Heinrich, H. W. (1950). Industrial accident prevention: A scientific approach. In McGraw-Hill Book Company, 1931. 366 pp. (3rd. ed., p. 366). McGraw-Hill Book Company. http://search.proquest.com/docview/58221472/4CB95185B4814FB5PQ/2

Helleloid, D., Nam, S.-H., Schultz, P., & Vitton, J. (2015). The U.S. airline industry in 2015. Journal of the International Academy for Case Studies, 21(5), 113–125.

Helmreich, R. L. (1998). Culture at work in aviation and medicine: National, organizational, and professional influences (1 ed.). Ashgate.

Hessburg, J. (2001). Air carrier MRO handbook (J. Hessburg, Ed.; 1st ed.). McGraw Hill.

Hirsch, B. T. (2006). Wage determination in the U.S. airline industry: Union power under product market constraints (SSRN Scholarly Paper ID 941127). Institute for the Study of Labor. https://papers.ssrn.com/abstract=941127

Hirsch, B. T., & Macpherson, D. A. (2000). Earnings, rents, and competition in the airline labor market. Journal of Labor Economics, 18(1), 125–155. https://doi.org/10.1086/209953

Hirsch, B. T., & Macpherson, D. A. (2020). Union membership and coverage database: IV. industry: Union membership, coverage, density, and employment by industry, 1983-2019. https://www.unionstats.com/

Holloway, S. (2008). Straight and level: Practical airline economics. Routledge. http://ebookcentral.proquest.com/lib/purdue/detail.action?docID=438715

Holt, M. J. (2002). Air carrier operations (1st ed.). Iowa State Press.

House Transportation & Infrastructure Committee. (2019, July 17). State of aviation safety. https://www.youtube.com/watch?v=CRPH4R8zWoU&list=PLeX3V_tR3nFw3CJZl-oY_MyJEdwsErhfR&index=1&t=1s

Huntington, S. P. (2003). The clash of civilizations and the remaking of world order (1st ed.). Simon & Schuster.

IATA's Maintenance Cost Technical Group. (2019). Airline maintenance cost executive commentary edition 2019. https://www.iata.org/contentassets/bf8ca67c8bcd4358b3d004b0d6d0916f/mctg-fy2018-report-public.pdf

International Civil Aviation Organization. (2018). The safety management manual (4th ed.). Author.

International Civil Aviation Organization. (2019). State of global aviation safety. Author. https://www.icao.int/safety/Documents/ICAO_SR_2019_29082019.pdf

Interviewee X. (n.d.). Linfeng Jin's stage 2 interviews [Personal communication].

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. Field Methods, 18(1), 3–20. https://doi.org/10.1177/1525822X05282260

Jakobsen, J. C., Gluud, C., Wetterslev, J., & Winkel, P. (2017). When and how should multiple imputation be used for handling missing data in randomised clinical trials – a practical guide with flowcharts. BMC Medical Research Methodology, 17(1), 162. https://doi.org/10.1186/s12874-017-0442-1

Jorge-Calderon, D. (2016). Aviation investment: Economic appraisal for airports, air traffic management, airlines and aeronautics. Routledge. https://www.taylorfrancis.com/books/9781317176718

Kalemba, N., & Campa-Planas, F. (2019). Safety and the economic and financial performance in the airline industry: Is there any relationship? Aviation; Vilnius, 23(1), 7–14. http://dx.doi.org.ezproxy.lib.purdue.edu/10.3846/aviation.2019.9744

Karanikas, N., Kaspers, S., Boer, R. J. de, Piric, S., & Roelen, A. (2016). Review of existing aviation safety metrics (No. S10931; RAAK PRO Project: Measuring Safety in Aviation, pp. 1–17). Aviation Academy, Amsterdam University of Applied Sciences. https://doi.org/10.13140/RG.2.2.35967.41128

Karanikas, N., Kaspers, S., Roelen, A., Piric, S., Aalst, R. van, & Boer, R. J. de. (2016). Results from surveys about existing aviation safety metrics. Aviation Academy, Amsterdam University of Applied Sciences. https://doi.org/10.13140/RG.2.2.22545.63847

Kim, L. H., Kim, D. J., & Leong, J. K. (2005). The effect of perceived risk on purchase intention in purchasing airline tickets online. Journal of Hospitality & Leisure Marketing, 13(2), 33–53. https://doi.org/10.1300/J150v13n02_04

Kinnison, H. A., & Siddiqui, T. (2012). Aviation maintenance management (2nd ed.).

Kraus, T. L. (2008). The Federal Aviation Administration a historical perspective, 1903-2008. U.S. Government Printing Office. http://purl.access.gpo.gov/GPO/LPS113201

Lederer, J. (1953, October 11). Safety in the air: Problems are being solved by infinite care and attention to technical details. New York Times, XX21.

Lee, S. G., Ma, Y.-S., Thimm, G. L., & Verstraeten, J. (2008). Product lifecycle management in aviation maintenance, repair and overhaul. Computers in Industry, 59(2), 296–303. https://doi.org/10.1016/j.compind.2007.06.022

Leib, S. M. (2014). ICAO safety management systems (SMS) development in environmental contexts: A field study of greater China. [Ph.D., Purdue University]. http://gateway.proquest.com/openurl?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&res_dat=xri:pqm&rft_dat=xri:pqdiss:3636337

Lercel, D. (2013). Safety management systems in FAA Part 145 repair stations: Barriers and opportunities [Ph.D., Saint Louis University]. http://search.proquest.com/docview/1426441281/?pq-origsite=primo

Leung, L. (2015). Validity, reliability, and generalizability in qualitative research. Journal of Family Medicine and Primary Care, 4(3), 324–327. https://doi.org/10.4103/2249-4863.161306

Li, Y., & Guldenmund, F. W. (2018). Safety management systems: A broad overview of the literature. Safety Science, 103, 94–123. Scopus. https://doi.org/10.1016/j.ssci.2017.11.016

Lichtenstein, A. (1998). Putting labor's house in order: The Transport Workers Union and labor anti-communism in miami during the 1940s. Labor History, 39(1), 7–23.

Lincoln, Y. S., & Guba, E. G. (1985). Naturalistic inquiry. Sage Publications.

Liou, J. J. H., Yen, L., & Tzeng, G.-H. (2008). Building an effective safety management system for airlines. Journal of Air Transport Management, 14(1), 20–26. https://doi.org/10.1016/j.jairtraman.2007.10.002

Lohr, S. L. (2010). Sampling: Design and analysis (2 ed.). Brooks/Cole.

Lu, C. (2003). An inductive study regarding nonregulatory maintenance resource management (MRM) training [Ph.D., University of Nebraska at Omaha]. In ProQuest Dissertations and Theses. http://search.proquest.com/docview/305234328/abstract/FCD48355DB1543D8PQ/1

Lu, C., Wetmore, M., & Przetak, R. (2006). Another approach to enhance airline safety: Using management safety tools. Journal of Air Transportation, 11(2), 113–139.

Łyszczarz, B., & Nojszewska, E. (2018). Economic situation and occupational accidents in Poland: 2002-2014 panel data regional study. International Journal of Occupational Medicine and Environmental Health, 31(2), 151–164. https://doi.org/10.13075/ijomeh.1896.01093

Mabotja, M. J., Mampana, N. J., Tavengwa, B., Walters, J., Mearns, M. A., & Swanepoel, E. (2019). An analysis of the demand for business aircraft among the corporate sector in South Africa. Journal of Transport and Supply Chain Management, 13(4), e1–e8. https://doi.org/10.4102/jtscm.v13i0.441

Machiavelli, N. (2017). The prince. CreateSpace Independent Publishing Platform. (Original work published 1532)

Mankiw, N. G. (2001). Principles of economics (2nd ed.). Harcourt College Publishers.

Mankiw, N., & Swagel, P. (2006). The politics and economics of offshore outsourcing. https://doi.org/10.3386/w12398

Mao, T. (1965). On practice. In Selected Works of Mao Tse-Tung (Vol. 1–5, pp. 295–309). Pergamon. https://doi.org/10.1016/B978-0-08-022980-5.50024-6

Marx, K., & Engels, F. (1969). Manifesto of the Communist Party. In Marx/Engels selected works: Vol. One. Progress Publishers. (Original work published 1848)

Massachusetts Institute of Technology. (2018). Glossary. http://web.mit.edu/airlinedata/www/Res_Glossary.html

Massachusetts Institute of Technology. (2020). Airline data project. http://web.mit.edu/airlinedata/www/default.html

McCue, C. (2006). An examination of changing firm structure in the aircraft engine industry [Ph.D., University of Connecticut]. In ProQuest Dissertations and Theses. https://www.proquest.com/docview/305322193/abstract/4AB4F25AA20A4410PQ/1

McFadden, M., & Worrells, D. S. (2012). Global outsourcing of aircraft maintenance. Journal of Aviation Technology and Engineering, 1(2), 63–73. https://doi.org/10.5703/1288284314659

Meier, A., & Rudwick, E. (1982). Communist unions and the black community: The case of the transport workers union, 1934–1944. Labor History, 23(2), 165–197.

Merriam, S. B. (2016). Qualitative research: A guide to design and implementation (4th ed.). Jossey-Bass, a Wiley Brand.

Monaghan, K. L. (2011). Examining the relationship between passenger airline aircraft maintenance outsourcing and aircraft safety [Ph.D., Northcentral University]. https://search.proquest.com/docview/855031301/abstract/C63EFB1607474F4DPQ/1

Moore, P. S. (2001). Aircraft industry and aviation maintenance school roles in the aircraft maintenance technician shortage [M.S., University of Alaska Anchorage]. In ProQuest Dissertations and Theses. http://search.proquest.com/docview/304769175/abstract/B3B528031CC840B8PQ/1

Morrell, P. S. (2007). Airline finance (3rd ed.). Ashgate.

Nader, R. (2015, February 13). Letter to Jeff Smisek, CEO of United Airlines. https://nader.org/2015/02/14/letter-to-jeff-smisek-ceo-of-united-airlines/

Nader, R., & Smith, W. J. (1994). Collision course: The truth about airline safety (1st ed.). McGraw-Hill, Inc.

National Transportation Safety Board. (n.d.). History of the National Transportation Safety Board. Retrieved March 30, 2021, from https://www.ntsb.gov/about/history/Pages/default.aspx

National Transportation Safety Board. (1996). Uncontained engine failure/fire, ValuJet Airlines flight 597, Douglas DC-9-32, N908VJ, Atlanta, Georgia, June 8, 1995 (ARICRAFT ACCIDENT REPORT AAR-96/03). Author. http://purl.access.gpo.gov/GPO/LPS109369

National Transportation Safety Board. (1997). Aircraft accident report in-flight fire and impact with terrain Valujet airlines flight 592 DC-9-32, N904VJ Everglades, near Miami, Florida May 11,1996 (AAR-97/06). Author. https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR9706.pdf

National Transportation Safety Board. (2004). Loss of pitch control during takeoff Air Midwest Flight 5481 Raytheon (Beechcraft) 1900D, N233YV Charlotte, North Carolina January 8, 2003 (ARICRAFT ACCIDENT REPORT NTSB/AAR-04/01; pp. 1–216). Author.

Nazeri, Z. (2007). Cross-database analysis to identify relationships between aircraft accidents and incidents [Ph.D., George Mason University]. http://search.proquest.com/docview/304736199/abstract/117D6B07D8984DFAPQ/1

NewMyer, D. A., Johnson, J. L. T. C. N., & Kaps, R. W. (1992). Airline unions since deregulation: The views of selected airline unions. Journal of Aviation/Aerospace Education & Research, 2(2). http://search.proquest.com/docview/1689632388/abstract/B977B779CD23498DPQ/1

Noronha, G., & Singal, V. (2004). Financial health and airline safety. Managerial and Decision Economics: MDE, 25(1). http://search.proquest.com/docview/206610459/abstract/2B8AF1C5D06D4F8CPQ/1

O’ Brien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. Quality & Quantity, 41(5), 673–690.

Office of Inspector General. (2002). FAA oversight of passenger aircraft maintenance (CC-2002–146). US Dept of Transportation, Office of the Secretary of Transportation, Office of Inspector General. https://www.oig.dot.gov/sites/default/files/cc2002146.pdf

Office of Inspector General. (2005a). FAA safety oversight of an air carrier industry in transition (AV-2005-062). Author. https://www.oig.dot.gov/sites/default/files/av2005062.pdf

Office of Inspector General. (2005b). Review of air carriers' use of non-certificated repair facilities (AV--2006--031). Author. https://www.oig.dot.gov/sites/default/files/av2006031.pdf

Office of Inspector General. (2007a). Aviation safety: FAA's oversight of outsourced maintenance facilities. Author.

Office of Inspector General. (2007b). Aviation safety: FAA oversight of foreign repair stations. Author.

Office of Inspector General. (2007c). Actions taken to address allegations of unsafe maintenance practices at Northwest Airlines [AV-2007-080]. Author.

Office of Inspector General. (2008). Air carriers' outsourcing of aircraft maintenance (AV-2008-090). Author. https://www.oig.dot.gov/library-item/29183

Office of Inspector General. (2010). FAA's oversight of American Airlines' maintenance programs (AV-2010-042). Author.

Office of Inspector General. (2013). FAA continues to face challenges in implementing a risk-based approach for repair station oversight (Audit Report AV-2013-073; p. 33). Author.

Office of Inspector General. (2019). FAA needs to improve its oversight to address maintenance issues impacting safety at Allegiant Air. Author.

Olaganathan, R., Miller, M., & Mrusek, B. (2020). Managing safety risks in airline maintenance outsourcing. International Journal of Aviation, Aeronautics, and Aerospace, 7(1), 7.

Oshri, I., Kotlarsky, J., & Willcocks, L. (2015). The handbook of global outsourcing and offshoring: The definitive guide to strategy and operations. (3rd ed., pp. 1–351). Palgrave Macmillan. https://doi.org/10.1007/978-1-137-43744-0

Oster, C. V., Strong, J. S., & Zorn, C. K. (2013). Analyzing aviation safety: Problems, challenges, opportunities. Research in Transportation Economics, 43(1), 148–164. https://doi.org/10.1016/j.retrec.2012.12.001

Parast, M., & Fini, E. (Ellie) H. (2010). The effect of productivity and quality on profitability in US airline industry: An empirical investigation. Managing Service Quality: An International Journal, 20(5), 458–474. https://doi.org/10.1108/09604521011073740

Park, H. M. (2011). Practical guides to panel data modeling: A step-by-step analysis using stata. International University of Japan.

Partnership for Public Service. (2019). Shutdown letdown: How the longest shutdown in U.S. history did lasting damage to our government and the people it serves (pp. 1–20). Author. https://docs.house.gov/meetings/GO/GO24/20190925/110042/HHRG-116-GO24-20190925-SD004.pdf

Patankar, M. S. (2004). Risk management and error reduction in aviation maintenance (1 ed.). Ashgate.

Patankar, M. S. (2019). Chapter 13—Maintenance resource management for technical operations. In B. G. Kanki, J. Anca, & T. R. Chidester (Eds.), Crew Resource Management (3rd ed., pp. 357–405). Academic Press. https://doi.org/10.1016/B978-0-12-812995-1.00013-0

Putting U.S. aviation at risk: The impact of the shutdown, House (2019) (testimony of Mike Perrone).

Perrow, C. (2011). Normal accidents: Living with high risk technologies-Updated edition. Princeton University Press.

Porter, M. E. (1980). Competitive strategy: Techniques for analyzing industries and competitors (1st ed.). The Free Press.

Porter, M. E. (2008). The five competitive forces that shape strategy. Harvard Business Review, 86(1), 78.

PR Newswire. (2019). Ralph Nader to address airline passenger safety at June 4 summit. PR Newswire. https://www.prnewswire.com/news-releases/ralph-nader-to-address-airline-passenger-safety-at-june-4-summit-300854876.html

Professional Aviation Safety Specialists. (2019). About PASS 2019. https://www.passnational.org/index.php/about-pass/about-pass

Quinlan, M. (2012). The “pre-invention” of precarious employment: The changing world of work in context. The Economic and Labour Relations Review, 23(4), 3–23.

Quinlan, M., Hampson, I., & Gregson, S. (2013). Outsourcing and offshoring aircraft maintenance in the US: Implications for safety. Safety Science, 57, 283–292. https://doi.org/10.1016/j.ssci.2013.02.011

Quinlan, M., Hampson, I., & Gregson, S. (2014). Slow to learn: Regulatory oversight of the safety of outsourced aircraft maintenance in the USA. Policy and Practice in Health and Safety, 12(1), 71–90. https://doi.org/10.1080/14774003.2014.11667798

Quinn, J. B., & Hilmer, F. G. (1994). Strategic outsourcing. Sloan Management Review, 35(4), 43–55.

Raghavan, S., & Rhoades, D. L. (2005). Revisiting the relationship between profitability and air carrier safety in the US airline industry. Journal of Air Transport Management, 11(4), 283–290. https://doi.org/10.1016/j.jairtraman.2005.01.003

Rankin, W., Hibit, R., Allen, J., & Sargent, R. (2000). Development and evaluation of the Maintenance Error Decision Aid (MEDA) process. International Journal of Industrial Ergonomics, 26(2), 261–276. https://doi.org/10.1016/S0169-8141(99)00070-0

Reason, J. (1997). Managing the risks of organizational accidents. Ashgate.

Reason, J. (2000). Safety paradoxes and safety culture. Injury Control and Safety Promotion, 7(1), 3–14. https://doi.org/10.1076/1566-0974(200003)7:1;1-V;FT003

Reason, J. (2003). Managing maintenance error: A practical guide. Ashgate.

Reason, J. (2016). Organizational accidents revisited. Ashgate.

Rebitzer, J. B. (1995). Is there a trade-off between supervision and wages? An empirical test of efficiency wage theory. Journal of Economic Behavior & Organization, 28(1), 107–129. https://doi.org/10.1016/0167-2681(95)00023-0

Reed, W. R., & Ye, H. (2009). Which panel data estimator should I use? Applied Economics, 43(8), 985–1000. https://doi.org/10.1080/00036840802600087

Rep. Markwayne Mullin (R-OK) News Release. (2018, May 9). Representatives Graves, Mullin, Lipinski, and Lawrence introduce Aviation Workforce Bill. Federal Information & News Dispatch. http://search.proquest.com/docview/2036721544/citation/B71259C20C2F49A0PQ/1

Rhoades, D., Reynolds, R., Waguespack, B., & Williams, M. (2005). The effect of line maintenance activity on airline safety quality. Journal of Air Transportation, 10(1), 58–71.

Ridge Global. (2018). Risks associated with foreign repair stations (pp. 1–56). Ridge Global LLC.

Romano, D. (2019, July 17). TWU President samuelsen blasts maintenance offshoring, toxic cabin air at ‘State of Aviation Safety’ hearing. https://www.twu.org/twu-president-samuelsen-blasts-maintenance-offshoring-toxic-cabin-air-at-state-of-aviation-safety-hearing/

Rose, N. (1990). Profitability and product quality: Economic determinants of airline safety performance. The Journal of Political Economy, 98(5), 944–964. https://doi.org/10.1086/261714

Rose, N. (1992). Fear of flying? Economic analyses of airline safety. The Journal of Economic Perspectives, 6(2), 75–94.

Rossman, G. B., & Wilson, B. L. (1985). Numbers and words: Combining quantitative and qualitative methods in a single large-scale evaluation study. Evaluation Review, 9(5), 627–643. https://doi.org/10.1177/0193841X8500900505

Royal Swedish Academy of Sciences. (1991). The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1991. Author. https://www.nobelprize.org/prizes/economic-sciences/1991/press-release/

Rucinski, T., & Shepardson, D. (2021, February 12). U.S. House committee approves another $14 billion for pandemic-hit airlines. Reuters. https://www.reuters.com/article/us-health-coronavirus-usa-airlines-idUSKBN2AC07X

Rudari, L., Johnson, M. E., Geske, R. C., & Sperlak, L. A. (2016). Pilot perceptions on impact of crew rest regulations on safety and fatigue. International Journal of Aviation, Aeronautics and Aerospace, 3(1), 4.

Rutner, S. M. B., & Brown, J. H. (1999). Outsourcing as an airline strategy. Journal of Air Transportation World Wide, 4(2), 22–31.

Salkind, N. J. (Ed.). (2010). Encyclopedia of research design. SAGE.

Salkind, N. J. (2012). Exploring research (8th ed.). Pearson.

Scheinberg, R. (2017). The commercial aircraft finance handbook (1st ed.). Taylor and Francis. https://www.taylorfrancis.com/books/9780203713303

Schniederjans, M. J., Schniederjans, A. M., & Schniederjans, D. G. (2006). Outsourcing management information systems. Idea Group Publishing.

Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill building approach (7th ed.). John Wiley & Sons.

Shapiro, C., & Stiglitz, J. E. (1984). Equilibrium unemployment as a worker discipline device. The American Economic Review, 74(3), 433–444.

Smith, A. (2007). An inquiry into the nature and causes of the wealth of nations. MetaLibri Digital Library. (Original work published 1776)

Sobieralski, J. B. (2020). COVID-19 and airline employment: Insights from historical uncertainty shocks to the industry. Transportation Research Interdisciplinary Perspectives, 5, 100123. https://doi.org/10.1016/j.trip.2020.100123

Spence, T. B., Fanjoy, R. O., Lu, C., & Schreckengast, S. W. (2015). International standardization compliance in aviation. Journal of Air Transport Management, 49, 1–8. https://doi.org/10.1016/j.jairtraman.2015.06.015

Staffing standards for aviation safety inspectors. (2006). National Academies Press. https://doi.org/10.17226/11742

Steele, J. B. (2015, December). The disturbing truth about how airplanes are maintained today. Vanity Fair, December. https://www.vanityfair.com/news/2015/11/airplane-maintenance-disturbing-truth

Stefani, A. (2003). Review of air carriers use of aircraft repair stations. Federal Aviation Administration, Report Number: AV-2003-047.

Stock, J. H., & Watson, M. W. (2003). Introduction to econometrics. Addison Wesley.

Stolzer, A. J. (2016). Safety management systems in aviation (2nd ed.). Routledge. https://www.taylorfrancis.com/books/9781315607504

The state of aviation safety: Hearing before the Subcommittee on Aviation of the Committee on Transportation and Infrastructure House of Representatives 115th congress 2nd session, House of Representatives, 2nd., 160 (2018) (testimony of Subcommittee on Aviation Staff).

Sullivan, J. V. (2007). How our laws are made (Revised and updated / by John V. Sullivan.). U.S. Government Printing Office. https://purl.fdlp.gov/GPO/LPS103850

Swamy, P. A. V. B., & Arora, S. S. (1972). The exact finite sample properties of the estimators of coefficients in the error components regression models. Econometrica, 40(2), 261–275. https://doi.org/10.2307/1909405

Tang, R., & Elias, B. (2012). Offshoring of airline maintenance: Implications for domestic jobs and aviation safety. Congressional Research Service.

Tashakkori, A., & Creswell, J. W. (2007). The new era of mixed methods. Journal of Mixed Methods Research, 1(1), 3–7.

The Federal Aviation Administration’s oversight of outsourced air carrier maintenance: Hearing before the Subcommittee on aviation of the Committee on Transportation and Infrastructure, House of Representatives, 110th Congress,1st session. (2007). U.S. Government Printing Office.

Tikkanen, A. (2021). Ralph Nader. In Encyclopedia Britannica. https://www.britannica.com/biography/Ralph-Nader

Torres-Reyna, O. (2010). Getting started in fixed/random effects models using R.

Transport Workers Union of America. (2018). The impact of offshoring U.S. aircraft maintenance to foreign repair. https://www.twu.org/wp-content/uploads/2018/05/The-Impact-of-Offshoring-Aircraft-Maintenance-to-Foreign-Repair-Stations.pdf

United Nations. (1994). Human development report. In Oxford University Press, Inc., 1994. Xi+226 pp. (p. xi+226). Oxford University Press, Inc. https://www.proquest.com/docview/59667737/9F523753F644A8DPQ/3

Definitions and Abbreviations, 14 Electronic Code of Federal Regulations § 1.1 (1962). https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=14:1.0.1.1.1.0.1.1

Repair Stations, 14 Electronic Code of Federal Regulations § 145.3 (2002). https://www.ecfr.gov/cgi-bin/text-idx?SID=5bfe2c14013a65c20d3f63ed71275367&mc=true&node=se14.3.145_13&rgn=div8

Uniform System of Accounts and Reports for Large Certificated Air Carriers, 14 Electronic Code of Federal Regulations § 241.04 (2002), Source: ER-755, 37 FR 19726, Sept. 21, 1972, unless otherwise noted. https://www.ecfr.gov/cgi-bin/text-idx?SID=0261bd536feb7e71a7746cf73f46858a&mc=true&node=pt14.4.241&rgn=div5#se14.4.241_104

Notification and Reporting of Aircraft Accidents or Incidents and Overdue Aircraft, and Preservation of Aircraft Wreckage, Mail, Cargo, and Records, 49 Electronic Code of Federal Regulations § 830.2 (2010). https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=83490280586fae601f3ebebb62d46738&rgn=div8&view=text&node=49:7.1.4.1.12.1.1.2&idno=49

Van Wagner, K. (2007). Cutting costs and cutting corners-the safety risks associated with outsourcing aircraft maintenance and the need for effective safety oversight by the federal aviation administration. J. Air L. & Com., 72, 631–656.

Vincoli, J. W. (2014). Basic guide to system safety (3rd ed.). Wiley.

Walala, M. (2016). A cross-sectional and mixed-method assessment of safety culture and safety climate at a regional airline [Ph.D., Purdue University]. http://search.proquest.com/docview/1831566004/abstract/FF3B97848E4C446FPQ/2

Weisberg, S. (2014). Applied linear regression (4th ed.). Wiley.

Wells, A. T. (2001). Commercial aviation safety (3rd ed.). McGraw-Hill.

Wensveen, G. J. (2011). Air transportation a management perspective (7th ed.). Ashgate.

Wiegmann, D. A., & Shappell, S. A. (2003). A human error approach to aviation accident analysis: The human factors analysis and classification system. Ashgate.

Wiener, E. L. (1977). Controlled flight into terrain accidents: System-induced errors. Human Factors, 19(2), 171–181. https://doi.org/10.1177/001872087701900207

Williams, M. J. (2020). Beyond 'context matters': Context and external validity in impact evaluation. World Development, 127, 104833. https://doi.org/10.1016/j.worlddev.2019.104833

Williamson, O. E. (1971). The vertical integration of production: Market failure considerations. The American Economic Review, 61(2), 112–123. JSTOR.

Williamson, O. E. (1985). The economic institutions of capitalism: Firms, markets, relational contracting. Free Press ; Collier Macmillan.

Williamson, O. E. (1991). Comparative economic organization: The analysis of discrete structural alternatives. Administrative Science Quarterly, 36(2), 219–244.

Williamson, O. E. (2008). Outsourcing: Transaction cost economics and supply chain management. Journal of Supply Chain Management, 44(2), 5–16. https://doi.org/10.1111/j.1745-493X.2008.00051.x

Williamson, O. E. (2010). Transaction cost economics: The natural progression. American Economic Review, 100(3), 673–690. https://doi.org/10.1257/aer.100.3.673

Wood, R. H. (2003). Aviation safety programs: A management handbook. Jeppesen Sanderson.

Wooldridge, J. M. (2013). Introductory econometrics: A modern approach (5 ed.). Cengage Learning.

Yu, S.-F. (2008). Price perception of online airline ticket shoppers. Journal of Air Transport Management, 14(2), 66–69. https://doi.org/10.1016/j.jairtraman.2007.11.002

Zapf, R. C. (2014). The relationship between labor unions and safety in US airlines: Is there a "union effect?" [University of North Dakota]. https://search.proquest.com/docview/1654999919?pq-origsite=summon