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A Literary Survey on the U.S. Airline Maintenance Outsourcing: Technology, Economics, and Politics Perspectives

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This study examines the U.S. airline maintenance outsourcing- a common business phenomenon in the post-1978 deregulated airline industry. Over the years, there have been several fatal accidents in the U.S. linked to airline maintenance outsourcing, and it has caught the attention of the government and general public. This paper went over the complex airline maintenance outsourcing factors from technology, economics, and political tripartite perspectives. And suggestions for the airlines, the regulators and the legislators are made in the end.

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In 2015, Mr. James Steele penned an article in Vanity Fair admonishing the current practice of U.S. airline maintenance outsourcing overseas as the disturbing truth. He asserted that the outsourced maintenance jeopardizes the aviation safety of U.S. commercial airline passengers because foreign mechanics are not the Federal Aviation Administration (FAA) certificated mechanics and their employers, known as maintenance repair and overhaul (MRO) operators, are less stringently overseen by the FAA (Steele, 2015). Mr. Steele's work is fraught with fear mongering partial truths. "Partial truths or half-truths are often more insidious than total falsehoods"(Huntington, 2004, p. 37). This paper aims to evince the public of the complex airline maintenance outsourcing factors involving the tripartite perspectives of technology, economics, and politics.

Introduction to Airline Maintenance Outsourcing

There are three reasons to ensure proper aircraft maintenance in the interest of three key stakeholders in commercial aviation. For the airlines, maintenance sustains the aircraft in a usable and punctual daily operation to receive revenue (Belobaba et al., 2016; Scheinberg, 2017). For the lessees who may be airlines or aircraft leasing companies 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 (Bourjade et al., 2017; 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 approved by the regulators (Holt, 2002; Scheinberg, 2017).

For those who work in commercial aircraft MRO industry, it is a well-known fact that airlines are not performing all the maintenance tasks anymore as they used to do before 1978. In 1978, U.S. President Jimmy Carter signed Airline Deregulation Act into the law and started the dismantling process of government economic control of U.S. carriers via the introduction of free market into the U.S. domestic airline industries. President Carter's action has brought about the gamut of positive economic effects for the public: a significant decrease in airfares, as well as a tremendous increase in passenger volume and cargo traffic (Belobaba et al., 2016; Bruce et al., 2018; Wensveen, 2011). The huge gain in the flying public pushes airlines into finding ways to cut the cost down. And one of proven cost-cutting strategies is outsourcing non-essential business functions (Görg & Hanley, 2004; Grossman & Helpman, 2005; Oshri et al., 2015; Porter, 1980).Between late 1990s and now, the U.S. airlines have outsourced the following functions: ticket sales and distribution, aircraft leasing, airport gates, complimentary limousine pick-up, food services, baggage handlers, aircraft interior cleaning, and after 2000s certain accounting functions, training, reservations, IT, frequent flyer programs, and non-airline functions such as property management) (Czepiel, 2003; Rutner & Brown, 1999). The raison d'etre for this outsourcing trend lies in the fact that the airlines find those functions are not generating enough profit or even worse stacking up the operation cost.

And aircraft maintenance is also in this outsourcing prone trend of daily airline operation. The U. S. General Accounting Office (GAO) estimated that nearly half of the U.S. airline maintenance had been outsourced to repair stations (1997). Transport Workers Union of America (TWU) (2018) reported 47% of U.S. airlines' total maintenance spending was spent on

outsourced maintenance, representing an astonishing $7.3 billion in expenditures, and some spending as high as 75% of their total maintenance costs on outsourced maintenance by 2016.

Czepiel, contracted by the FAA (2003) and the U.S. Department of Transportation Office of Inspector General (DOT 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 requires more specialized training and more costly equipment and labor, to the MRO providers. The airline industry is sensible to economic cycles, introduction of new aircraft models, and retirement of aging aircraft; therefore, by adopting an outsourcing strategy, airlines can minimize the impact of economic waves and tap the benefits of technology changes through a small number of competent, well-trained mechanics in-house (Belobaba et al., 2016; Bennett & Craun, 1996; Bourjade et al., 2017; Fischer et al., 2008; GAO, 2004; Nader & Smith, 1994; Perrow, 2011). In the eyes of airline management, the successful capability of line maintenance and light maintenance is the core competency of airline maintenance, and it could influence the safe operations of the airlines (McFadden & Worrells, 2012; Quinn & Hilmer, 1994; Rhoades et al., 2005).

Outside the airline inhouse maintenance, there are repair stations who perform contracted maintenance work for multiple airlines' similar aircraft and aircraft components, and they enjoy the greater economies of scale (Bazargan, 2016; Bazargan & Hartman, 2012; Smith, 1776/2007). Notably, the MRO industry is enjoying cheaper labor rates and currency exchange rates by conducting heavy maintenance business in developing countries (Czepiel, 2003; Mankiw & Swagel, 2006; Quinlan et al., 2013). Comparative advantages of lower wages, reduced facility investment, and friendly government policies have drawn outsourced heavy maintenance to developing countries such as China and El Salvador (Tang, 2018; Zwerdling, 2009). Besides these comparative advantages, the specialized shops within the repair stations are able to tackle complex maintenance tasks in the heavy maintenance visits, and these tasks are not limited to structural repair and modification, corrosion control and treatment, and component maintenance activities on the communication and navigation equipment, landing gear, auxiliary power unit (APU), and myriad miscellaneous subsystems (McFadden & Worrells, 2012). Moreover, original equipment manufacturers (OEM) are also increasingly involved with outsourced maintenance work. After sales of their products, they continue providing airline customers with the remote engine health monitoring and aircraft/engine leasing services (Belobaba et al., 2016; Scheinberg, 2017). They form conglomerates with major repair stations and launch 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). For instance, engine maintenance is a lucrative aviation MRO and safety-critical business. 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 full authority digital engine (or electronics) 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.

Safety Threats

Contract maintenance providers compete with each other on the basis of cost-reduction and time efficiency (Bağan & Gerede, 2019; Bazargan, 2016; DOT OIG, 2008). This may lead 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"-removing a known good part of in-service aircraft and installing it on another aircraft and the 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; R. 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; GAO, 1997, 2016; Quinlan et al., 2013, 2014). Finally, the spillover effects are that seemingly unrelated events may have particularly negative impact on the maintenance work quality (Quinlan, 2012; Quinlan et al., 2013).

The other safety threat factors include victims of poor ergonomic and biomechanical working conditions like work-related hearing loss, musculoskeletal injuries (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 may 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 on aviation safety (Bağan & Gerede, 2019; CBS 2 News Morning-Supervisor goes on tirade after american airlines mechanic writes up safety concern, 2019; Rhoades and Waguespek., 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 summarizes it as "In God we trust. Everyone else we check" (Hessburg, 2001, p. 36). And the gravest consequence for poorly outsourced maintenance is a crash, and two such deadly aviation accidents related to aircraft maintenance outsourcing factors are discussed below.

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 Miami International airport. A total of 110 people on board including two pilots, three flight attendants, and 105 passengers perished in this accident. The National Transportation Safety Board (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 by design.

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 (NTSB, 1997). It is noteworthy that the NTSB (1997) did not find any preexisting mechanical faults that may have contributed to the accident. Class D cargo compartments have been eliminated as of 1998, and remaining class D cargo compartments have been converted to class C or E by 2001.

Air Midwest Flight 5481 Accident

On January 8, 2003, a fully loaded Beechcraft 1900D with two flight crew and 19 passengers failed to take off and crashed into a 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 incorrect rigging of the elevator control system combined 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 was lack of oversight of the work being performed at the Huntington, West Virginia, contracted 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 above highlight the technical aspects of risks from outsourced maintenance, and they touched upon some aspects of individual organizational factors. It is also worthwhile to look at interested stakeholder views on airline maintenance outsourcing from political and economic perspectives.

Airline Labor Union

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 (GAO, 2003; Zapf, 2014). The airline labor unions include pilots unions, mechanics unions, and industry unions, which includes service agent unions (GAO, 2003; Wensveen, 2011). They negotiate with their airline management through collective bargain involving the threat of strikes (Chaison, 2007; Hirsch, 2006). In the U.S., collective bargaining is governed by the Railway Labor Act passed in 1926 (GAO, 2003; Wensveen, 2011). It has three intentions: minimize the disruption of commerce in the travel industry by resolving labor disputes, maintain the status quo in terms of objective work conditions and practice, and prohibit either side from interfering with, influencing, or coercing their counterpart's choice of representatives (GAO, 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 contracts 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 wield 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. Additionally, 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 for 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 enhanced 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 safe and smooth operations of highly complex systems such as airline operations involving both flight operation and ground maintenance (Chang & Wang, 2010; Patankar, 2004, 2019; Perrow, 2011; Reason, 1997; Wiegmann & Shappell, 2003).

The Aircraft Mechanics Fraternal Association (AMFA) has lobbied congressional members to introduce H.R. 5701, an Aviation Workforce Development Pilot Program Bill that encourages the younger generation 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; these are all efforts that can and will improve aviation safety (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 due to their size of operation (Arnold, 2019; Helleloid et al., 2015). Moreover, maintenance labor unions such as Transport Workers Union of America (TWU) and AMFA often claim outsourced maintenance hurts aviation safety, as 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 possessing FAA A&P mechanic certificates), have limited English proficiency, and suffer an inadequacy of stringent oversight from the FAA (Ridge Global, 2018; Romano, 2019; TWU, 2018).

Airline Management

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 such as aircraft comprise 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, the 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; GAO, 2004; Porter, 2008). Currently, airline management generally considers that aircraft maintenance is a non-value-added activity, and they are strong advocates of employing aircraft maintenance outsourcing to lower operating cost (Bazargan, 2016; GAO, 2004; McFadden & Worrells, 2012). Another advantage of outsourced maintenance, from airline management's perspective, is the ability to circumvent organized union strikes that can 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 avoiding the negative impacts from unions, another roadblock drives airline management to outsource airline maintenance is the fact that the airlines do not possess enough capacity to maintain all their aircraft; instead, they choose to reserve in-house maintenance for "critical needs" work, which is 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 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 to 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 certain traits, including large and diverse fleet composition and extensive geographic networks; however, most importantly, they own a huge capacity of hangar space, equipment, and maintenance labor force, allowing them to absorb other contract maintenance work to generate additional profit, including work from their rivalry companies (Al-kaabi et al., 2007). In short, MRO service for competing airlines is fungible, satisfies the scale economy, and creates reputation effects (Williamson, 1985).

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 proved to be an inefficient system, as it presented 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 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 (FAA, 2016b).

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 aviation stakeholders through advisory circulars (ACs) and seminars and provides training for 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 in directing 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 most, the outsourced airline maintenance activities could get oversight from the FAA (provided that it is done in a FAA Part 145 repair station), foreign

regulators (if offshored), airlines, and MRO contractors; the oversight are guaranteed through the civil aviation regulations and company policies. In their own entities, different units have their own oversight as listed below. At most, the outsourced airline maintenance activities could get oversight from the FAA (provided that it is done in a FAA Part 145 repair station), foreign regulators (if offshored), airlines, and MRO contractors; the oversight are guaranteed through the civil aviation regulations and company policies. In their own entities, different units have their own oversight as listed below.

Table 1

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 the DOT OIG, 2008, p. ii.

Undoubtedly, the FAA, as a regulator, is an important layer in accident prevention by providing oversight of maintenance safety for both in-house and outsourced maintenance (Cusick et al., 2017; Perrow, 2011; Reason, 1997), but it often encounters difficulties such as inflexibility of bureaucracy, slow responses to technology, lack of funding, limited number of qualified aviation safety personnel, and government shutdowns (Ballesteros, 2007; DOT OIG, 2002; Monaghan, 2011; Moore, 2001; Nader & Smith, 1994; Partnership for Public Service, 2019; Quinlan et al., 2014).

GAO and DOT OIG

As the watchdogs for the federal government, the U.S. Government Accountability Office (GAO) and the Department of Transportation Office of the Inspector General (DOT 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, and the, (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 FAA complied with all the recommendations except updating the regulations governing the oversight of repair stations and certification and training requirements for maintenance personnel due to the prolonged process of revising and adding new law (GAO, n.d.).

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 obstacles 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 Air Transportation Oversight System (ATOS) program by December 31, 2007, so the FAA discontinued the evaluative process (GAO, n.d.).

The GAO (2016) found that 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, to ensure 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), which is a risk-based, data-supported oversight system to help standardize how its inspectors identify safety risks in planning and conducting oversight of 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 reasons that there is a lack of compelling safety cases supporting the recommendation, thus compliance with the recommendation is useless and burdensome for the agency (GAO, 2005).

The DOT OIG (2002) found the FAA slow to implement the Air Transportation Oversight System (ATOS), an aviation safety oversight system. The FAA has failed 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 DOT 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 DOT OIG (2005) 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 DOT 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. Detailed key regulatory differences are given below.

Table 2

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 the DOT OIG, 2005, p. 12. Copyright 2005 by Author.

The DOT OIG (2007c) 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 3

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 the DOT OIG, 2007, p. 6. Copyright 2007 by Author.

In the same document, the DOT 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 (DOT OIG, 2007b).

The DOT 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 DOT 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 DOT 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 the FAA (DOT OIG, 2007a). 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 (DOT OIG, 2010), and regulators' failure to use SAS, the new oversight system (DOT OIG, 2019).

Congress

The airline industry makes very significant contributions to the U.S. economy. The number tells the story, in 2020, airline operations has brought 156.1 billion to the GDP, and airline annual expenditures run as high as 519.2 billion). In 2016, these two amounts contributed 3.6% of the U.S. GDP (FAA, 2016a, 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).

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 Federal Aviation Administration's Oversight of Outsourced Air Carrier Maintenance, 2007; 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; Romano, 2019). A detailed Congressional report indicated that there is no concrete evidence showing airline maintenance outsourcing had affected aviation safety, but specific areas related to FAA oversight and the incapability of foreign repair stations were found to be legitimate concerns (Tang & Elias, 2012). Additionally, the U.S had maintained a positive trade balance in aircraft MRO at the time (R. Tang & Elias, 2012).

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 on airline maintenance outsourcing is not centered only on technology and economics, but there is also political interest. Politicians and candidates often taunt and run campaigns with specific agendas to stop outsourcing and keep the jobs in their electoral districts and supporters. However, the bills they introduce paint a different picture. The Congressional Progressive Caucus which consists of the predominant presence of Democrat has been doing legislative work to push back the airline maintenance outsourcing trend. Airline maintenance outsourcing issue becomes one origin of political struggle. In the recent 116th Congress (2019-2021), two members in the Democratic Party's Progressive Caucus in the House of Representatives made efforts to curb airline maintenance outsourcing.

The first proposal was from U.S. House Representative John Garamendi (Democratic Party – California). Garamendi (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. And the bill was introduced and there was no further movement.

The second proposal was from U.S. House Representative Peter DeFazio (Democratic Party – Oregon), who assumed the Chair of the House Committee on Transportation and Infrastructure. DeFazio (2019) introduced "Safe Aircraft Maintenance Standards Act.". This bill requires that all overseas repair stations have at least one unannounced inspection each year, and 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 TWU, AMFA, and the International Brotherhood of Teamsters. The air transport industry and airline labor unions have made significant political donations to the congress members who introduced anti maintenance outsourcing legislations. Their campaign campaigns fund, classified by industry, are listed in the tables below (Center for Responsive Politics, 2020b, 2020a).

Table 4

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 5

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.

Rep. DeFazio successfully won reelection in 2019, and he held Chair of the House Committee on Transportation and Infrastructure for the 117th Congress. His "Safe Aircraft Maintenance Standards Act" took on the new name of "Global Aircraft Maintenance Safety Improvement Act," and it passed in the House.

Lobbyist

In addition to unions, airlines, MRO providers, and U.S. government agencies, there are special interest groups who lobby Congress members in the fight between pro-outsourcing and anti-outsourcing airline maintenance work. The following lobbyists are commonly present in the discussion of airline maintenance outsourcing in Congressional debate or statements to certain legislation activities.

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 (ARSA, n.d.). The Managing Director & General Counsel of ARSA, Mr. Filler, addressed Congress in 2007. Filler (2007) stated 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 (2019), "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" (ARSA, 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 airfare adjusted for inflation dropped from $490 in 1995 to $355 in 2019. To keep operating and other costs low, more and more airlines are outsourcing their maintenance to third parties, so that they are able to offer lower ticket prices to entice price-sensitive passengers(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 if those repairs are 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 the high profile groups is the Airline Consumer Action Project (ACAP), which was 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 diverse union membership are the FAA safety inspectors, and they are in line with the airline labor unions to oppose airline maintenance outsourcing, especially airline maintenance offshoring. PASS supports the legislation proposed by the Democrat Congress members (DeFazio, 2019; Garamendi, 2019). PASS has offered compelling 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 outsourcing: The FAA lacks a viable staffing model to maintain adequate inspectors to oversee outsourced maintenance work as confirmed by the National Research Council (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 (2005), and these constraints impede the Certificate Management Office (CMO) and International Field Office (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 and alcohol policies and no unannounced inspections on foreign soil (DOT OIG, 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 airlines to use non-certificated repair stations, which the FAA does not need to inspect by law (DOT OIG, 2005; The Oversight of Foreign Aviation Repair Stations, 2007).

In the 2019 House Committee on Transportation and Infrastructure-Subcommittee on Aviation hearing, the PASS addressed the longest government shutdown, and also the most costly to the U.S. economy in U.S. history $8 billion 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). Furthermore, the furlough of the FAA frontline employees is a persistent phenomenon accompanied by the government shutdowns through the history regardless of which party is in control of the Legislative or Executive branches (Edelberg, 2019; Fischer et al., 2008; R. Tang & Elias, 2012).

In October 2022, one of the authors grasped a unique chance of asking Mr. Dan Elwell, who served the Acting Administrator of the FAA (January 6, 2018 – August 12, 2019) during the 35-day shutdown in a Q&A session of his speaking event, how will the FAA avoid furloughing frontline employees like aviation safety inspectors in the time of shutdown in the future? Mr. Dan Elwell explained that the government shutdown was the fallout of "two chambers [Democrats and Republicans] playing political football," and he recalled that President Trump pulled him into the White House, asked him about the stress of government shutdown on the national aviation resilience and safety. Mr. Elwell spoke highly of his team. They were responsible professionals who still reported to work. Additionally, Elwell reminded the audience that all the furloughed employees were eventually compensated for the income loss during the furlough, and finally, he admitted that he did not know the exact answer to this question (Jin, 2022).

Conclusion

What is reasonable is real; that which is real is reasonable. Airline maintenance outsourcing is a reality that we have to live with. The top priority for an airline is to make money; it cannot do so without strong safety records. An important by-product of safety, provided by the incessant pursuit of safety goals, is an incremental improvement of efficiencies (Cusick et al., 2017). In the U.S., airlines maintenance outsourcing is turning into a contentious political issue in Congress and it involves with stakeholders of airline unions, airline management, elected politicians, and other lobbyists. People with different identities use politics to advance their own interests. After this long journey of exploring airline maintenance outsourcing, the researchers wanted to offer following suggestions:

1. The airlines should try to establish a precise model that determines outsource/insource maintenance business plan to save money and improve efficiency/safety.

2. The 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, they could hire more experienced and qualified inspectors.

3. The government should not pass radical legislation that coercively changes the supply-and-demand market relationship of outsourced maintenance to favor special interest groups. The conscientious legislators should consider the following question posed by Fred Hayek, "Whether in the particular instance [establishment of the new law] the advantages gained are greater than the social costs which they impose" (Hayek, 1944, p. 39)?

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