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Impact of Lightning Strikes on Airport Facility and Ground Operations

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Lightning strikes may wreak havoc on airports, causing minor to substantial destruction worth millions of dollars. This study focuses on incidents that occurred at United States airports between 1996 and 2020, including death, injury, infrastructure damage, worker compensation claims, and airline delays. Even though the study showed a modest number of fatalities and injuries, any fatality is unacceptable. According to the study, infrastructure damage also included flight delays. During this analysis, two such costs to air traffic control towers at large airports were revealed.

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Airports are hazardous places to work, particularly in inclement weather. Lightning has the potential to disrupt airport operations. "Over the last 30 years, approximately 50 fatalities occurred by lightning strikes each year, with many more suffering permanent disabilities" (OSHA, 2016, p 1). Lightning can damage buildings, communications systems, electrical circuits, and powerlines, strike ground crew workers, and destroy airfield electrical systems, resulting in millions of dollars in losses (GHRC, 2021). Lightning struck the Baltimore Washington International (BWI) Air Traffic Control Tower in 2013, injuring one of the controllers (Gresko, 2014). After FAA Inspectors completed their inspection of the tower grounding system, investigators discovered "one cable designed to take electrical current from a lightning strike to the ground had been cut during construction" (Associated Press, 2014, p 1).

Lightning warning systems detect electrical activity in the atmosphere and send an alert based on the energy detected, a more accurate indicator of a lightning strike. The system notifies the public 20 minutes before a lightning strike within a two-mile radius, allowing them to seek shelter (Engle, 2015). There will be times when lightning can appear but no alarm sounds because the energy of the lightning strikes in the area is outside the measured range. However, there will be times when the alarm goes off, but no visible lightning strikes occur (Engle, 2015). Training the airport and tenants on the warning systems allows those on the ramp a warning to take cover when the alarm system goes off. False alarms delay airline operations unnecessarily.

Lightning is dangerous because it strikes any day or night, even in clear blue skies. The fact that lightning can hit more than 100 miles from the parent thunderstorm makes it dangerous (Robbins, 2017). For example, lightning from a sunny sky struck and killed a 7-year-old girl during softball practice, according to Lane Kelley (1998) of the South Florida Sun-Sentinel. Lightning strikes have occurred at airports with clear blue skies and fatally injuring aircraft mechanics.

Problem Statement

Weather alerts and lightning detection systems effectively warn individuals of severe weather and the threat of lightning strikes. Lightning detection systems are an integral part of a comprehensive lightning safety program to minimize threats to passengers and employees. Despite the advancements in technology, these systems are reactive because they issue alerts once lightning is detected. At this time, these systems cannot accurately predict when and where lightning strikes will occur. Lightning strikes have damaged buildings, communications equipment, airfield electrical systems, and struck passengers and employees. What is more, the threat of lightning strikes causes work stoppages, which result in delayed flights. Flight delays induced by lightning near airports are not only costly for airlines since all operations must be halted but also expensive for airports and the federal government to infrastructure damage, injuries, and deaths. Airports could invest in lightning warning systems to avoid potentially life-threatening circumstances, and each airport and tenant should develop policies and procedures

for their organization to follow in the event of a lightning strike. Implementing the FAA's best practices may minimize the number of deaths or injuries. The primary purpose of this study was to evaluate the magnitude of the problem that lightning strikes pose to airports. With so many lightning strikes in the US, there was an unanticipated dearth of data on airport-specific lightning injuries and deaths, as well as the expenditures connected with infrastructure damage. The research team aimed to solve the following issues: 1) What effect did lightning strikes have on airport operations, and were there any fatalities or injuries to airport staff, tenants, or passengers because of such strikes? 2) To what degree are airport-specific lightning strikes causing infrastructure damage? 3) What regulations and procedures do airports, airlines, and tenants follow during severe weather events? 4) To what extent, if any, are airport personnel compensated for injuries directly caused by lightning? To answer these questions, extensive data were collected and analyzed to draw meaningful conclusions.

Literature Review

Ramp and airport personnel face many hazards daily when operating in the Airport Operations Area (AOA). Lightning is one of nature's most awe-inspiring phenomena. Lightning is harmful to the aviation industry because it jeopardizes outside ramp activities such as aircraft fueling, luggage handling, restaurant service, and tug operations (Mostajabi et al., 2019). Lightning strikes can cause infrastructure damage or affect airport operations in various ways (Steiner et al., 2014a). Lightning also causes severe electromagnetic interference, damaging electrical circuits, buildings, and other exposed built structures such as transmission lines, wind turbines, and photovoltaics (Mostajabi et al., 2019).

The initial thunderstorm lightning strikes may be the most dangerous, not because of their strength, but due to the element of surprise (Duclos et al., 1990). Because warning systems rely on detecting lightning strikes, ground personnel may not be alerted of a lightning strike because lightning must strike before a signal can be transmitted (Bloemink, 2013). That makes airport ramp workers the most vulnerable to lightning, as they must be relocated indoors until the lightning stops, effectively shutting down ramp operations (Heitkemper et al., 2008). Many lightning fatalities are caused by both the inability and reluctance to get to a safe area in a timely way. Many people wait much too long to begin their journey to safety, putting them in a perilous and perhaps fatal scenario (Jensenius, 2020). Operators would prefer to avoid the delay caused by ramp closures, but the process of closing and restoring a ramp is fraught with significant uncertainty (Steiner et al., 2014a).

Steiner et al. (2014b) stated delays are created by the distractedness of the person in charge of making judgments on-ramp closures. Other operational responsibilities (such as being on the phone or away from their workstation) might generate similar distractions, keeping them from concentrating on the lightning decision support tool (p. 7). According to the research of Steiner et al. (2014b), actual ramp closures frequently lagged the little time when a ramp closure should have begun based on the lightning information and safety rules used by a specific stakeholder. Delays may occur because airlines must adhere to schedules and ground turnaround times. Passengers board and disembark, refuel, cater, and load or unload cargo during these airline turnarounds. Accidents occur when ground crews work quickly. Working too quickly can endanger both aircrews and passengers. Employees may be an inducement to remain exposed, or

people may be obliged to continue working. Workplace injury protection may necessitate regulations and guidelines that differ from those provided by the National Weather Service (Duclos et al., 1990).

Lightning-related ramp closures are unavoidable to guarantee the safety of outdoor employees, as false warning alarms or prolonged ramp closures create avoidable inefficiencies that operators would like to eliminate. Lightning monitoring and alerts about the start and duration of threats are among the safety procedures in place at major airports. The specifics vary significantly amongst operators, but one thing they all have in common is that they use lightning information to trigger work pauses and stop outdoor activities, albeit mostly in response to already occurring lightning (Steiner et al., 2014a). When airplanes that are currently occupying gates are unable to be prepped for departure and are delayed, there are eventually no more gates accessible for arriving planes. As a result, arriving taxiing aircraft must wait in a designated location until their allocated gate becomes available or divert to another airport (Steiner et al., 2013).

Even though some airports use lightning detection systems to safeguard personnel and tenants, without defined regulations, each tenant will select when they can begin moving aircraft from the gate for departures or allow passengers to disembark if they arrive without a gate allocated. Due to the lightning warning, planes parked at gates cannot be serviced, and arriving flights may not be able to locate a free entrance to discharge their passengers (Steiner et al., 2014a). Airport ramp closures, which cause ground operations to halt, are examples of lightning exposure (Holle et al., 2016). Observations and alerts are used as safety precautions when warning systems at an airport are unavailable; the decision to close the ramps is understood to depend on flash data. According to the National Weather Service, the sound of thunder travels a mile in roughly 5 seconds. One could determine the distance to the lightning in miles by calculating the seconds between the flash of lightning and the sound of thunder, then dividing that number by 5.

At the time of Bloemink's research (2013), no system could predict where lightning would strike within a specific timeframe (Bloemink, 2013). However, researchers at the Ecole Polytechnique Fédérale de Lausanne (EPFL) School of Engineering discovered they could predict when lightning would strike using artificial intelligence and standard meteorological data to the nearest 10 to 30 minutes within a radius of 18.61 miles (Mostajabi et al., 2019). This system can cover any remote region from radar and satellite range and unavailable communication networks (Ecole Polytechnique Fédérale de Lausanne, 2019).

Lightning data from Low Frequency (L.F.) networks is frequently used by airport and airline parties in their decision-making process about ramp closures. The meteorological factors of a site influence the use of lightning detection and warning systems at airports, as well as the geographic distribution of Cloud to Ground (C.G.) lightning strikes across the United States (Heitkemper et al., 2008). Major airports have safety protocols, including lightning monitoring and alerts concerning the beginning and duration of dangers (Steiner et al., 2014b).

Grabowski et al. (2005) published an article titled "Ground Crew Injuries and Fatalities in Commercial Aviation in the United States, 1983-2004." The purpose of the study was to "investigate airport ground crew injuries and fatalities involving aircraft of commuter air carriers

and major airlines" (p. 1). This study found that 98 ground crewmembers were injured or killed in 80 accidents throughout the 22-year study. According to these researchers, 26 percent of these accidents resulted in ground crew fatalities. From the investigation findings, only one ground crew member died due to electrocution while wearing a headset connected to the aircraft when lightning struck the aircraft tail (Grabowski et al., 2005). The number of airplane ramp injuries and deaths is assumed to be low, according to Tarmier and Kisielewicz (2012), and no effort has been made to collect data into a systematic database because such instances are not needed to be reported to authorities.

The FAA may assist airports and airlines by implementing a ground stop until the airport is declared safe to operate. The FAA maintains the gates open due to flight delays and aircraft ramp waits until airlines use them safely. At the NAS level, traffic management initiatives like Ground Delay Program, Ground Stop Program, and Airspace Flow Program limitations attempt to reduce incoming traffic to an airport or geographical area (FAA, 2009).

The Federal Emergency Management Agency (FEMA) estimates that about 300 people are injured by lightning each year; about 10% of those struck by lightning die (Mader, 2020). Lightning strikes are not going away, as the planet warms, lightning strikes in the United States will increase by 50% by the end of the century (Brooks, 2014; Romps et al., 2014).

Lightning is an erratic natural force that can strike at any time and in any location, even when the skies are clear and blue. The initial strikes are the most lethal. Commercial flight delays are common when there is lightning in the area, and the ramps are cleared of support personnel. Major airports have lightning warning systems in place, occasionally giving false-positive results. As a result, airlines have experienced unnecessary delays. Even though no single approach could predict the time and location of a lightning strike during the research, researchers could narrow time and distance to a potential strike by using artificial intelligence and standard meteorological data. Lightning strikes are expected to rise due to global warming, placing airports, airlines, employees, and customers at risk.

Materials and Methods

One goal of this study was to determine the impact of lightning strikes on airport operations and if such strikes resulted in fatalities or injuries to airport staff, tenants, or passengers. To do this, in-depth research was conducted using two distinct sources of information, including official data and media sources.

Government Records

Data was acquired from several government agencies, including the National Oceanic and Atmospheric Administration (NOAA) and the Centers for Disease Control and Prevention (CDC). The National Centers for Environmental Information (NCEI) and the National Weather Service are both parts of NOAA (NWS).

National Centers for Environmental Information

The NCEI receives storm data information from the NWS (NCEI, 2021). Researchers analyzed this database by examining lightning injuries and fatalities from 1996 through 2020. On the website, a search for lightning strikes and the year was performed under the tab labeled "Narrative Text Search" by typing, for example, "lightning strikes 1996." A list of occurrences was downloaded into Microsoft Excel® for examination. After downloading each year, each event narrative was checked for mention of lightning strikes on airports and categorized. Data gathered included the event, state, report source, dates, deaths, injuries, property damage expenses, and narrative.

National Weather Services

For data, the researchers went to the National Weather Service database. This database contained additional information not available in the NCEI listing. Such as specific names of people killed, albeit this information lacks the story supplied by the NCEI database. When the year of lightning deaths was selected, the data provided the city, state, location, activity being done, and name of the individual who died.

By choosing the year under the information on US Lightning Deaths, the NWS database offered U.S. Lightning Deaths by year: A listing of events would include the place and activity, as well as the individual's name. These individual reports were reviewed for events that occurred at an airport. For example, in 2017, one fatality shows in the city of Jacksonville NC, the location is Tarmac, and the activity was working on aircraft, along with the victim's name. (NWS, 2021). This database site also includes a listing of U.S. lightning deaths since the 1940s titled: "80-year List of Severe Weather Fatalities" (NWS, 2021). This listing covers all lightning, tornado, flood, and hurricane fatalities from 1940 – 2020.

Additional information was downloaded from this same database site, by selecting "Storm Data Publication" under "Storm Events Database". From this location, each annual report was then downloaded from the select publication listing. Scrolling to the lightning fatalities for that year would provide all lightning fatalities that occurred that year per state These annual summaries also provided the total lightning injuries from 1996 to 2011 (NCDC, 2021). Since these annual reports only covered through 2011, another source was pursued. Under the NWS Weather Related Fatality and Injury Statistics, U.S. Summaries, each year from 1996 through 2020 were found to provide both the fatalities and injuries. Data from these two databases were compared for accuracy between the two sources.

Media Sources

Even though the NCEI gets information from the media, not every incident is recorded. Some recorded occurrences were discovered by a detailed search of numerous databases, including Newspaper Source Plus, Nexis Uni, Proquest, Newsbank Access World News Research Collection, and Google Scholar.

Newspaper Source Plus and Nexis Uni are news transcript databases that include news from newspapers, television, and radio. The criteria used within these sites were "lightning strikes" or "Airports", or "Airfields". The search produced articles (377,557 in total) that covered U.S. newspapers, newswires, radio, and television news transcripts.

To be consistent with the dates obtained through government records, the researchers of this study primarily analyzed these databases for articles from 1996 to 2020.

Each airport-related mishap was further studied by combing through newspaper stories regarding that specific incident. These databases contain information on the occurrence, the state, the county, direct and indirect deaths, injuries, property damage, and a narrative of the incident. Strikes involving airport staff, ramp workers, airline passengers, and visitors to the airport for a specific reason, such as an air show or an airport open house, were discovered throughout the search. Also, discovered during this search were articles that pertained to lightning strikes on airports where the injured individual filed worker compensation claims against the airport and airline.

The outcome of those worker compensation claims articles that contained the name of the individual, the date, and the place was then explored through that city or county court system.

All data was collected and downloaded into a Microsoft Excel® spreadsheet for further evaluation. Any occurrence that did not include lightning strikes at an airport was excluded from further investigation. Any reports that were duplicated were also deleted.

Results and Discussion

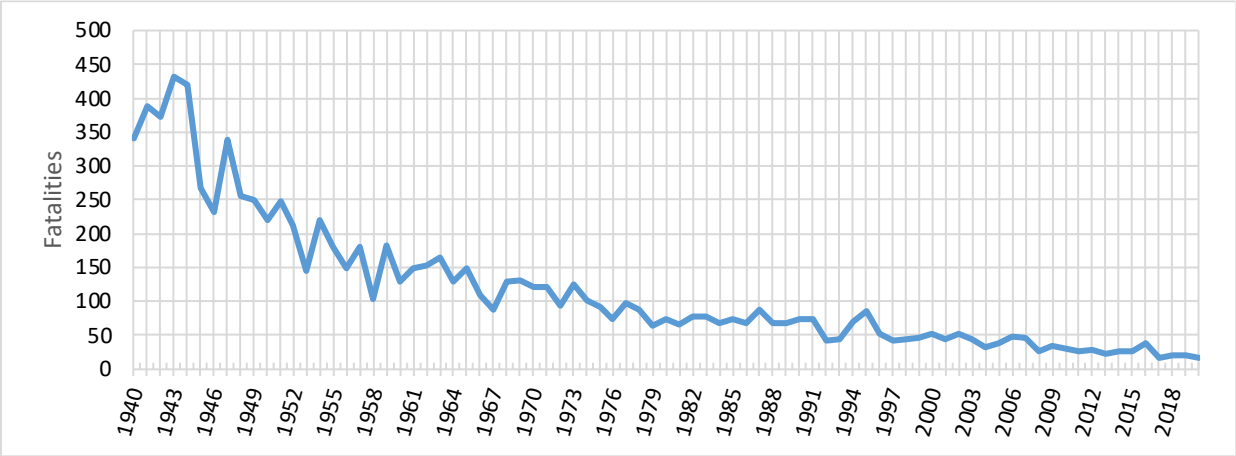
One goal of this study was to determine the impact of lightning strikes on airport operations and if such strikes resulted in fatalities or injuries to airport staff, tenants, or passengers.

It is noteworthy to observe that long-term lightning mortality in the United States has decreased from 432 fatalities in 1943 to 17 deaths in 2020. (Figure 1). This huge drop might be attributed to education, modern medical techniques, and people migrating from farmlands to rural regions (Borenstein, 2017; Robbins, 2016). More than one-third of all lightning-related deaths occur on farms (CDC, 2021). 16,925 lightning strikes were observed and assessed between 1996 and 2020. 867 persons were killed and 5,126 were wounded in the 16,925 lightning strikes (NWS, 2021).

With so many lightning strikes in the US, there was an unanticipated dearth of data on airport-specific lightning injuries and deaths, as well as the expenditures connected with infrastructure damage. The researchers were interested in the effects of lightning strikes on airport operations, as well as if such strikes resulted in fatalities or injuries to airport employees, tenants, or passengers.

This data was limited to records from 1996 to 2020 to examine based on data received from NOAA's National Centers for Environmental Information website. Each individual complaint was then evaluated to ensure that it was a lightning strike on an airport.

Figure 1
U.S. Lightning Strike Fatalities from 1943 to 2020



(Source: www.weather.gov/hazstat/)

During these 25 years, three fatalities were reported: one was an airline passenger released from the plane to walk to the terminal, another was an aircraft mechanic working on a plane in Florida, and the third was an aircraft mechanic working on an aircraft in North Carolina (Table 1). The researchers also discovered 93 airport worker injuries were caused by lightning strikes from 1996 to 2020 (Table 1). Some of these workers filed worker compensation claims. At the time of writing, the researchers discovered that two worker compensation claims were denied compensation due to "Acts of God," and one was approved in the court system.

Figure 2
Injuries caused by lightning strikes at airports between 1996 and 2020

The most significant number of airport injuries from lightning strikes occurred in 2000, out of all the resources used. Half of those 18 injuries occurred in a single incident on May 18, 2000, when lightning struck the steel superstructure of a new terminal under construction at Detroit Metro Airport, injuring nine (9) construction workers (Figure 2).

Table 1
Documented Lightning Fatalities and Injuries at Airports from 1996 -2020

State	Fatality	Injury	Total
Florida	1	33	34
Alabama		9	9
Michigan		9	9
Oklahoma		7	7
Georgia		5	5
Kentucky		4	4
Arkansas		3	3
Minnesota		3	3
Hawaii		3	3
North Carolina	1	1	2
Texas		2	2
Kansas		2	2
New Jersey		2	2
Tennessee		2	2
Illinois		1	1
South Carolina	1		1
Arizona		1	1
Iowa		1	1
Maryland		1	1
New Mexico		1	1
West Virginia		1	1
Maine		1	1
Wyoming		1	1
TOTALS	**3**	**93**	**96**

Of all the lightning strikes (16,935) there were three fatalities that occurred at airports (Table 1). Those three deaths are detailed in the case reports that follow. There were 28 individual lightning strikes reported in the NWS database that damaged infrastructure costing $1,151,310. None of the federal facilities, repair or replacement costs, or delay costs, were included in our total estimated costs (Table 2).

Case 1. When a lightning storm passed within 5 miles of the Marine Corps Air Station at New River in July 2017, workers working on the flight line were ordered to leave. Both mechanics were on their way out of the MV-22 Osprey when it was struck by lightning. Skyler Dean James, 23, was ruled brain dead five days after he and another Marine mechanic were hurt on July 11 at Marine Corps Air Station New River in Jacksonville (Smith, 2017).

Case 2. In June 2015, Passengers sat on the plane for 45 minutes in Columbia, waiting for the weather to clear before they were ordered off the plane, even though thunderstorms approached. Passenger Sonya Dockett was running from the aircraft to the concourse when she was struck by lightning in full view of her son. Dockett collapsed and was carried unconscious and suffering from burns into the terminal, only to be pronounced dead in August 2016 in her

home in Connecticut. Social media reported a woman was struck by lightning as she deplaned onto the tarmac to walk into the terminal at Columbia Metropolitan Airport. Ms. Dockett eventually died from her injuries on August 5. Ms. Dockett's husband brought this to court in 2016 based on a Wrongful Death and Negligent Infliction of Emotional Distress against American Airlines, Inc, PSA Airlines Inc., and Piedmont Airlines, Inc. (Mills, 2015; Mills, 2016). A settlement for a confidential amount was awarded to the family in 2020.

Case 3. In April 1996, eleven military employees were working on an aircraft at Hurlburt Field when lightning struck the plane or nearby. One airman was killed, and ten more were injured. Because of thunderstorms in the vicinity earlier in the morning, the workers had been advised to stay indoors. At 8:29 a.m., the airmen were permitted back on the field, and lightning struck at 8:38 a.m. The strike that hit the airmen was most likely the initial strike from a developing thunderstorm (NWSD, 2021).

A second goal of this research was to determine to what extent are infrastructure damages due to airport-specific lightning strikes.

"Facility Damage" refers to lightning strikes that damaged airport beacons, runways, taxiways, ramps, electrical systems (including runway lighting), ATC equipment, and weather equipment but did not provide an estimated cost for repairs or replacements (Table 1). Lightning struck the Dallas Fort Worth (DFW) Airport, destroying "transmission equipment in the Terminal Radar Approach Control room causing delays to the traveling public. Until the equipment was repaired, DFW Airport resorted to backup transmitters. Approximately "600 aircraft were delayed and 425 were canceled at DFW Airport as well as 135 aircraft were delayed and 65 were canceled at Love Field" (Jimenez & Cardona, 2019).

Table 2
Lightning Estimated Damage to Airport Infrastructure and Total Events per year from 1996 – 2020

Year	Fatalities	Injuries	Airport Est. Costs	Facility Damage	Total Events
2020		4	$1,000		246
2019		2		4	343
2018				1	396
2017	1	4			365
2016		3	$70,110		409
2015	1	3	$10,000		403
2014		3	$70,200	1	498
2013			$131,500		471
2012			$153,000		591
2011		2	$53,000	1	765
2010		3	$455,000	2	864
2009		2		2	721
2008		3			795
2007			$16,000		722
2006		7		1	840
2005			$3,500	5	864
2004				2	715
2003		3	$56,000	2	741
2002		6			875
2001		3	$87,000	2	880
2000		18			909
1999		4		2	863
1998		2	$40,000		899
1997		6		2	838
1996	1	15	$5,000	1	918
Totals	**3**	**93**	**$1,151,310**	**28**	**16,931**

Cost of Delays

Federal Air Traffic Control Towers, transmission equipment, TRACONs, weather stations, and radar towers were among the installations damaged by lightning. Lightning struck multiple Air Traffic Control Towers, creating significant delays in air traffic. Among those reported during this study were Atlanta-Hartsfield, BWI, Fort Lauderdale, Southwest Florida International, Orlando, Miami, and Tampa International Airports.

When lightning struck the Baltimore Washington International (BWI) Air Traffic Control Tower in 2013, the total direct cost of lightning-induced delay and cancellation was $1,887,850 (Ding & Rakas, 2015).

On April 23, 2009, lightning struck the Hartsfield–Jackson Atlanta International Airport Air Traffic Control Tower. Following the strike, the tower was briefly evacuated, and heavy storms caused a power outage in the region. Due to storm and wind shear occurrences, all arrivals and departures at the world's busiest airport were halted (Canadian Press, 2009). The

estimated total direct cost of this event's lightning-induced outage delay and cancellation was more than $2 million ($2,287,261) in delay costs and $168,948 in cancellation costs from eight weather-induced cancellations (Ding & Rakas, 2015).

Lightning struck a mobile lounge (transporter) at Dulles International in 2007 when it was traveling from Terminal B to the Main Terminal. While crossing taxiway bravo, lightning struck the lounge, causing the shuttle to come to a halt. After being restarted and on its way to the terminal, lightning struck again, knocking it out of commission. No one was hurt on the mobile lounge, but damage to the mobile lounge included two blown-out windows and tire damage (Angel et al., 2007). This damage was projected to cost $10,000 (Figure 3).

Figure 3
Mobile Lounge damaged by Lighting, Dulles International Airport, 2007.

Source: (Angel et al., 2007, p. 378)

Locating Lightning Systems

The foundation of the warning equipment employed at various airports is lightning detecting systems. These devices are programmed to respond to the first lightning strike that occurs within a certain distance of the sensor. There are risks that notices will not be sent if the first strike occurs on-site. The ideal situation would be to have a system to predict a lightning strike within a specific time frame. Unfortunately, such a system does not currently exist (Bloemink, 2013).

Policies and Procedures

A third objective of this research was to determine what, if any, policies, and procedures are used by airports, airlines, or tenants use during these weather events. A survey was presented

by Randy Bass (2015) on Lightning Warning Procedures for Ramp Closures at US Airports during the 17th Conference on Aviation, Range, and Aerospace Meteorology. His findings indicated that larger airports have some form of policies to address lightning but vary from one airport to another. Of those airports that do have policies, some require the fueler to have such a policy and some leave it up to the airline. Those small and regional airports that responded to the survey reported they do not have such policies. Most airports surveyed reported they do not have a policy in place due to liability issues.

According to the National Fire Protection Association – 407 Standard for NFPA 407. Standard for Aircraft Fuel Servicing, section 4.2.10, Lightning: states that "written procedures shall be established to set the criteria for when and where fueling operations are to be suspended at each airport as approved by the fueling agent and the airport authority" (NFPA 407, 2022, p. 407-10).

Airports either do not have policies and procedures for lightning strikes for all airport tenants to follow, or state these policies and procedures are voluntary. Most general aviation airports do not have warning systems and must rely on telephone alerts to keep general aviation and fixed base operators informed or they receive no alerts at all. For those airports that lack policies or procedures, implementing the FAA's best practices may minimize the number of deaths or injuries would be a great option for some airports (Appendix A).

Alert System and Notification

One alert system reviewed was at Southwest Florida International Airport, which uses Thor Guard warning sensors (Figure 4). ThorTV was used to discover lightning strikes in the Florida areas surrounding airports such as Tampa International.

According to Heitkemper et al., (2008) research, there are many techniques by which airport staff and tenants were either notified of impending lightning strikes. Some airports do not alert tenants of a potential threat, while others tell airport workers through radio or telephone. Some airport operations centers at major commercial service airports collaborate with airline ramp tower employees to notify the air traffic control tower, aircraft fuelers, and aircraft servicing trucks of approaching dangers.

Figure 4.
Thor Guard (VOT) Sensor at RSW

Note: Photo Courtesy of Thomas Long

The Thor Guard lightning warning systems, like other systems, have been progressing to be more predictable and accurate than past technology has provided. ThorMobile allows the public to access lightning warnings through their smartphones around those airports that have Thor Guard technology, such as the one shown in Figures 5a, b, and c, for Tampa International Airport, Florida provides anyone access to ThorTV or ThorMobile to provide up to date data using a computer system or Smartphone. The system has four alerts; All Clear, Warning, Caution, and Red Alert, three of which are shown below.

Figure 5a
ThorTV All Clear

Figure 5b
ThorTV Warning

Figure 5c
ThorTV Red Alert

All Clear signifies that the area is safe, while Caution suggests that the atmosphere may be in flux. Warning indicates that energy changes in the atmosphere, but it may pass by, and Red Alters implies that safety is jeopardized (Thor Guard, 2021).

Terminal Docking Stations

Southwest Florida International Airport has installed a docking system at three concourses to be used during inclement weather. These docking systems allow planes to land and taxi to a gate without the assistance of ramp personnel. The docking systems indicate whether the pilot should proceed to the left, to the right, or come to a complete halt. To locate aircraft, these systems employ infrared cameras and laser sensors. The first docking system was built at D10 gate (Figure 6). Concourses B and C quickly followed (Shaw, 2019).

Figure 6
Docking Station Gate D10 RSW Terminal.

Photo Courtesy of Jeremy Valcich, RSW Operations, 2020

Aircraft ground marshaling

According to the above-stated Grabowski et al. (2005) study, one tug driver was towing an aircraft with his headset attached to the aircraft when lightning struck the aircraft's tail. An electrical current was sent through the headset electrocuting the tug driver. In 2017, at Southwest Florida International Airport, an aircraft was being towed from the gate in preparation for taxing to takeoff when lightning struck the aircraft's tail. The only difference between this and the previous occurrence was that in the Southwest Florida accident, another lineman disconnected the headset when the lightning hit the aircraft's tail, resulting in the linemen being hospitalized. The tug driver escaped unscathed. A lightning warning system was activated during the lightning strike on the airplane in the latter instance.

These incidents necessitated changes to airport policies, terminal amenities, and training programs. Since most airports do not have written policies, the FAA has established "Suggestions for Lightning Safety Procedures and Capabilities at Airports" (Bass, 2019).

Another solution is to construct terminal docking stations at each gate, which would allow planes to approach without jeopardizing ground crew safety. This technique works well for arrivals; however, for pushbacks, additional procedures must be performed.

A solution for pushbacks would be to use E-Vehicles to transfer aircraft from terminal gates to taxiway openings as an approach to protecting line staff from lightning strikes. In 2018, Fraport AG and Lufthansa tested E-Vehicle tugs by pulling back jets like the B737 and A320 using remote-controlled aircraft tugs (Toczauer, 2018). When this tug is used in conjunction with the aircraft ground radio frequency to the cockpit, the aircraft may push back during inclement weather without risking lightning strikes to the lineman.

Figure 7
Lightning Safety Informational sign in Lee County Parks.

Courtesy of Lee County Parks

Finally, loading and unloading freight during storms is currently not a possibility. As reported by Youssef Rddad of the Arkansas Democrat-Gazette (2019), "A 52-year-old Arkansas man was recovering at home Wednesday after a bolt of lightning "came out of the blue" and struck him hours earlier as he was loading an airplane at the Clinton National Airport in Little Rock" (Rddad, 2019).

Notifying the Public

During inclement weather, commuters traveling from open-air parking lots to terminals are not shielded from lightning strikes, nor are those passengers deplaning aircraft to walk across the ramp to the terminal. When a lightning warning system is activated at an airport, travelers are completely unaware of what danger the siren indicates. One cause of concern is the general public's lack of understanding of the processes that may be followed when an airport warning system is activated.

Flight crews and operations personnel are briefed on the warnings and procedures to follow to seek refuge. Airports can learn how other organizations communicate the importance of public notices. The Lee County, Florida - Parks Administration has installed lightning detection warning systems in its county parks, which has been a valuable technique for the public to learn from this type of sign. The County installed instructional signage throughout the parks to inform visitors what to do if the siren and lights go off (Figure 7). A warning system like this one at Jackson Hole Wyoming Airport could have prevented the medical doctor / CEO of the hospital from being struck by lightning as he walked from the airport to the parking lot (Hallberg, 2019).

Injured Workers Claims

According to the study's results, a total of 93 individuals (airport employees, tenants, and passengers) were harmed. The researchers' final goal for this study was to discover if airport workers were compensated for injuries directly caused by lightning. From 1996 until 2020, three worker compensation applications were filed, and three court judgments were issued. The researchers' ability to discover all those who applied for workers' compensation was limited by knowing the individual's name, date of occurrence, and location.

Workers Compensation & The Law

The workers' compensation procedure and the rules that regulate it are intricate and differ from state to state. Employers are required by law to acquire workers' compensation insurance. Although workers' compensation insurance might be expensive, it is required to safeguard companies and employees against job injuries (Insureon n.d.). In 2019, private companies in the U.S. reported 2.8 million nonfatal workplace injuries (*Insureon* n.d.). Moreover, these same companies in 2019 lost almost $62 billion related to lost time due to workplace injuries (*Insureon* n.d.). Workers' compensation insurance is based upon no-fault coverage which protects the employer from employee lawsuits resulting from workplace injuries; however, it also protects employees injured in the workplace (*Insureon* n.d.). It does not matter who is to blame for the employee's injury because an employee can be compensated if they made the mistake that resulted in their injury. Also, an employee does not have to prove the employer was at fault as well (Hoffmann, 2020). Workers' compensation insurance may cover employee costs such as medical bills, lost wages, and disability benefits.

Lightning strikes are referred to as an "Act of God," but this does not eliminate the employees' right to seek workers' compensation benefits (Hoffmann, 2020; Roffis et al., 2019). It is important to note that an "Act of God" does not guarantee the employee's workers' compensation claim will be approved. There are several criteria that need to be satisfied to seek workers' compensation benefits.

1. Did the employee need to be at the workplace at the time of the incident? Was the employee on the clock?
2. Was the employee traveling to or from work at the time of the incident?
3. Was the employee assigned to that specific job location where the incident occurred (Hoffmann, 2020)?
4. Did the employee work in conditions that increased the likelihood of being injured by lightning as compared to the public (Standler, 2004)? Indeed, an employee being asked to work on the airport ramp, during local thunderstorm activity, places the employee at an increased risk of injury from a lightning strike as compared to the public.
5. What if the employer could not reasonably foresee the risk of lightning strikes? Is the employer still liable for any injuries sustained by the employee due to a lightning strike?

Airports and airport tenants have a legal obligation to protect their employees. Airports have a legal obligation to protect employees, passengers, and visitors from lightning strikes.

What is more, airports have an obligation to provide warnings to employees, passengers and visitors, urging them to seek shelter because of the imminent danger of lightning (Standler, 2004). If the airport fails to uphold this obligation, it may be liable for injuries or fatalities that result from lightning strikes. In other words, if an employee is injured, while working at the airport, the employee may be eligible to receive workers' compensation benefits. "The defendant's failure to provide shelters with lightning protection, or to use appropriate warning technology, is an act of Man that is the basis for plaintiff's litigation" (Standler, 2004, p. 19). However, the airport or an airport tenant normally cannot be found accountable to pay compensation for injuries caused by not issuing a lightning warning that the employer cannot reasonably anticipate and protect against, such as lightning strikes during clear blue sky (Standler, 2004).

The Workers Compensation Claim Process

It is the employer's responsibility to inform their employees of the workers' compensation claim process. If an employee is injured at the workplace, they need to report the incident to their employer as soon as possible. Employees located at airports have a specified period to notify their employer of any injury that occurs at the workplace. The law varies, depending upon the state, but typically employees have approximately 30 days to notify their employer of an injury sustained while at work (Insureon, n.d.). Once an employer is notified by an employee of an injury sustained at the workplace, the employer must provide the employee with a workers' compensation claim form. It is the employer's responsibility to provide the employee with information detailing the employee's rights and benefits provided by workers' compensation (Insureon, n.d.).

Next, the employer is responsible for submitting the workers' compensation claim form, along with the required documentation. It is essential for the employer to keep accurate and thorough records regarding workplace incident. Once the claim is submitted by the employer, the insurance company will approve or deny the claim. If the workers' compensation claim is approved by the insurance company, the employee can accept the offer or negotiate with the insurance company. However, if the claim is denied the employee can file an appeal with the state's workers' compensation board (Insureon, n.d.). There are many reasons why a workers' compensation claim may be denied. For example, a claim may be denied if it can be proven the injury was self-inflicted or caused by misbehavior. The employer may need to be asked to provide information during the claim process, so it is imperative that all documentation is thorough and accurate. The goal is for workers to recover from their injuries and return to work.

Court Cases

What happens when a workers' compensation claim is denied, or the employee cannot reach an agreeable settlement with the insurer? Sometimes it comes to this: court. Employees at airports that have sustained injuries due to lightning strikes, have been denied workers' compensation benefits, and have taken legal action against their employer. Robert Clark took such action against United Airlines when he was struck by lightning while working at National Airport as a line mechanic. On September 24, 1975, Mr. Clark was working a flight at National Airport and was struck by lightning (*Clark v. United Airlines, 1982).* Mr. Clark sustained injuries

because of the lightning strike and was unable to work for eleven days. A workers' compensation claim was filed after the incident and United Airlines paid Mr. Clark his salary for eleven days and his medical expenses (*Clark v. United Airlines, 1982*). Mr. Clark claimed that he continued to suffer from pain in his knee, due to the lightning strike incident, between September 24, 1975, and January 19, 1979. Mr. Clark's physician could not confirm that Mr. Clark's knee pain was from the lightning strike incident. Mr. Clark sought legal action against United Airlines when the company refused to continue paying his medical expenses. Mr. Clark lost his workers' compensation case because the statute of limitation was two years for workers' compensation claims in Virginia. Mr. Clark received his last workers' compensation benefits in December 1975, so his final opportunity to file an additional workers' compensation claim was December 1977 (*Clark v. United Airlines, 1982*).

On August 11, 2017, Cary O'Donoghue was working at Dulles Airport while employed by United Airlines. That day there were thunderstorms in the area and the ramp had been temporarily closed earlier that day due to safety concerns resulting from the thunderstorms in the area and the associated lightning (*O'Donoghue v. United Cont'l Holdings,* 2019). Once the ramp reopened, O'Donoghue was preparing for the arrival of a United Boeing 787 aircraft at the airport gate where he was working. Once the aircraft arrived at the gate, O'Donoghue began his work on the ramp to service the aircraft. There are some important facts of the case that needs to be considered. First, the airport had experienced heavy rain that day and there were puddles of standing water on the ramp. Second, the Boeing 787 is a newer aircraft that is constructed of metal and composite material. Finally, the Boeing 787 does not need to be connected to a ground power unit while at the gate because the aircraft used its lithium batteries to power the aircraft while sitting at the gate. During the flight, aircraft can accumulate static electricity; however, the static electricity is dissipated once it is connected to the ground power unit (*O'Donoghue v. United Cont'l Holdings*, 2019).

On the evening of August 11, the Boeing 787 parked at the gate where Mr. O'Donoghue was working. As he approached the aircraft, he noted that it was still raining and there was lightning around the airport. Mr. O'Donoghue approached the aircraft with a metal ladder and placed the ladder in a puddle of water near the aircraft. He climbed the ladder and opened an access panel on the fuselage of the aircraft. The fuselage of this aircraft is constructed with composite material. He then touched a toggle switch that operated the cargo door of the aircraft. When he touched the toggle switch, he reported seeing a blue arc and felt electricity move through his body (*O'Donoghue v. United Cont'l Holdings,* 2019). Mr. O'Donoghue did not report seeing a blue flash on any other part of the aircraft. He reported to his supervisor that he was struck by lightning and immediately sought medical attention. The ramp at Dulles Airport was temporarily closed again after this incident.

It cannot be confirmed if Mr. O'Donoghue's injuries were the result of a lightning strike or the discharge of static electricity. The aircraft was not connected to a ground power unit so there was no opportunity to dissipate any static electricity that had accumulated during the flight. However, it would be determined an "Act of God" if Mr. O'Donoghue sustained the injury due to a lightning strike. Mr. O'Donoghue filed a workers' compensation claim but was denied. The Court of Appeals of Virginia ruled the evidence did not identify the aircraft or the employment activities as causes of his injuries. Subsequently, the court upheld the decision to deny him

workers' compensation benefits. According to Virginia law, an employee sustaining an injury due to a lightning strike while at work does not entitle the employee to workers' compensation benefits. Mr. O'Donoghue had to prove that the tasks or location of the work being performed put them at a higher risk, than the general public, to sustain injuries due to a lightning strike. Furthermore, it could not be proven that the injury was the result of a discharge of static electricity from the aircraft or a lightning strike. Based upon these findings, Mr. O'Donoghue was denied workers' compensation benefits (*O'Donoghue v. United Cont'l Holdings*, 2019).

On July 22, 2017, Austin Dunn was working at Southwest Florida International Airport while employed by Navstar Aviation. The airport's lightning alarm system was activated on July 22 while Mr. Dunn was at work. The other Navstar Aviation employees went inside the terminal building when the lightning alarm system was activated, but Mr. Dunn and two coworkers remained on the ramp to continue pushing back a Sun Country flight for departure ("Airport Worker," 2018). After the aircraft was pushed back from the gate, Mr. Dunn reached into the aircraft access panel to disconnect his headset cord from the aircraft. As he did so, lightning struck the tail of the aircraft and traveled through the aircraft and into his body ("Airport Worker," 2018.). The lightning strike caused injuries to his arms, legs, torso, head, and internal organs ("Airport Worker," 2018.). Mr. Dunn hired an attorney to ensure he received adequate workers' compensation benefits due to his injuries. The attorney stated that Mr. Dunn, along with his two coworkers, was told by the pilot of the aircraft to remain on the ramp to push back the aircraft ("Airport Worker," 2018). Mr. Dunn reached a settlement agreement, with NavStar Aviation, in the amount of $150,000 (*Austin Dunn v. WGA NavStar Aviation USA*, 2019).

There are many more workers' compensation claims, such as these, that demonstrate the difficulty for employees at airports to receive workers' compensation benefits sustained by lightning strikes. The workers' compensation laws are complex and vary depending upon the state where the incident occurs. Employees at airports are at an increased risk of being injured by lightning strikes due to the airport environment. Due to this increased risk of injury, it is imperative that airports develop a comprehensive lightning safety program to minimize the threat to employees.

Conclusion

Most airports in the United States have been found to use visual counting of lightning strikes to avoid risk. Not all the major commercial airports have invested in warning system technology, and those that have can upgrade their systems when new technology improves tracking accuracy and reduces delays. Because not every incident has been documented, only those that have been discovered to have been reported have been counted. As new technology becomes accessible, public warning communication has improved considerably in terms of precision and location of the imminent hit. During this investigation, there were only a few fatalities among all the lightning strikes in the United States. Not to diminish a fatality, since one fatality is too many, but airport fatalities are incredibly minimal when compared to the total fatalities in the United States during this study period. Of those injuries at airports, only three worker compensation claims were identified. Those were only discovered by publications that revealed the identities of lightning victims.

Lightning strikes are anticipated to increase by 50% over the next decade due to Global warming. As a result, airports must improve their technology and policies to warn the public about this potentially lethal force. The expenses of these unavoidable strikes are rising.

Because of the lack of standardization in the aviation industry's lightning safety policies, numerous airlines may apply noticeably different restrictions even at the same airport. Airports and airlines should inform passengers and airport tenants about warning alerts issued by the airport or airline and follow the necessary procedures.

Recommendations for Future Research

As global warming increases, airports become increasingly vulnerable to lightning strikes. Certain types of public notices, according to the study's findings, must be handled not only by airports but also by airlines. Although airports cannot eradicate the disastrous effects of lightning strikes, further study into how airports might lessen these damages and reduce delays is required. Because airplanes are not grounded when operating, it would be useful to investigate which injuries and deaths happened after lightning strikes while the aircraft was physically grounded, and repair was being conducted.

Future studies will include a more in-depth examination of the language in airport policies and procedures relating to lightning strikes, as well as the construction of a Benefit-Cost Analysis based on loss of life and injuries vs the purchase and implementation of established warning systems and processes.

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