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Significance of Incorporating Weather Technology Training for GA Pilots to Curb Fatalities

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As the weather warms and climate change become more extreme, pilots both in the air and on the ground are facing new challenges. Temperature increase, rising sea level, stronger headwind, turbulence, thunderstorm, and high altitude icing are causing a significant impact on aviation (Pearce, 2018). In the United States, about 77% of aircraft operations fall under the general aviation (GA) category. There are more than 300,000 GA aircraft in the US which are flown by approximately 600,000 pilots (Federal Aviation Administration [FAA], 2009). General aviation accidents cause approximately "seven hundred and thirty-five (735) fatalities per year" (Grabowski, Curriero, Baker, & Li, 2002, p. 398). The recent report stated that the average accident rate was "6.51 fatalities for every 100,000 flight hours in GA category" (National Transportation Safety Board [NTSB], 2014, p. 1). The average annual cost associated with GA accidents in the United States ranged between "$1.64 billion and $4.64 billion and cost of per accident was $950,000 and $2.70 million" (Sobieralski, 2013, p. 24). The same study estimated that the "total cost associated with the 31,050 general aviation accidents that occurred from 1994 to 2011 ranged between $29.5 billion and $83.7 billion" (Sobieralski, 2013, p. 24). Due to the number of fatalities and the cost related to accidents, general aviation safety is considered of vital importance. As per the FAA reports, it is one of the challenges not completely resolved (FAA, 2009).

The weather was identified as the probable cause for "2,983 GA accidents that occurred between 2002 and 2013" (Ortiz, Blickensderfer, & King, 2017, p. 1861). Ortiz, Blickensderfer, Johnson, Johnson, Caldwell, & Beringer (2017) reported that approximately 87% of GA accidents are weather- related. The advanced technologies available today, such as the glass cockpit and radar availability based on satellite information, promote safe flying. The FAA is carrying out research programs such as the Weather Technology in the Cockpit (WTIC) program, and the Aviation Weather Research Program (AWRP) to reduce the impact of weather on the national airspace system. Despite all these technological advancements, the weather still pose a threat to aviation safety. This research will focus to get an overview of weather-related accidents, to identify different weather hazards that cause accidents and also to determine which weather hazard is the major contributor to general aviation accidents. Further, this research study will also identify gaps in pilot training for weather hazards which will determine whether there is a need to tailor pilot training programs to reduce weather-related accidents.

Literature Review

General Aviation and GA Accidents

General Aviation (GA) operates under Title 14 Code of Federal Regulations, Part 91 (14 CFR Part 91) for a non-commercial purpose (Shappell &

Wiegmann, 2017). When compared with military and commercial operations, the accident rate is higher among GA operations and accounted for 83% in 2004 (Jarboe, 2005). Approximately two-thirds of all the weather-related accidents caused fatalities in general aviation operations (National Transportation Safety Board [NTSB], 2014).

Weather Hazards in General Aviation Accidents

Different features of the atmosphere such as wind direction, wind strength, air pressure, variation in temperature, and the way the earth heats up and cools down causes weather phenomena. This phenomenon is experienced during a flight as wind shear, thunderstorm, turbulence, and icing. Knowledge about the weather will help pilots to make proper decisions during an actual flight (Lester, 2007).

Wind. In general aviation operation, during take-off and landing, the wind is the main cause for the loss of directional control, which leads to accidents and fatalities. Wind shear can interrupt the normal altitude of a flight and affect its performance (FAA, 2016a). Wind shear is related to jet streams, thunderstorms, microbursts, and frontal surfaces. It causes turbulence which is a silent threat that can affect any flight and is often not detected (Lester, 2007); wind contributes to approximately 50% of all weather-related accidents (Austin & Hildebrand, 2014).

High-density altitude. At higher altitude, air density will be low, which adversely affects aircraft performance. The factors that contribute to high-density altitude are altitude, temperature, and humidity. Each of these factors will decrease the performance of an aircraft. This combination undesirably affects the take-off and landing distance, climb rate, as well as decreases the horsepower of the engine (FAA, 2008; Lester, 2007).

Icing. The term icing refers to the deposition of ice on an aircraft surface (Cao, Tan, & Wu, 2018). Depending on the type and severity, icing might disrupt the aerodynamic reliability, or affect the airflow by forming horns near the top and bottom of the wings. Icing can change the aerodynamic configuration and reduce the aerodynamic performance of an aircraft, block pitot tube and static vents, decrease the performance of radios, affect the airflow and the stability even leading to loss of control of the aircraft, and the only option is to return to safer airspace (Cao et al., 2018; FAA, 2016,a).

Carburetor icing. Another form of icing that adversely affects the general aviation industry is carburetor or induction icing. Carburetor icing refers to the formation of ice in the fuel induction system. In an aircraft with a fixed-pitch propeller, carburetor icing reduces the rpm of the engine and in aircraft with a constant-speed propeller, it decreases in manifold pressure. If proper action is not taken by the pilot it could cause engine roughness, vibration, decrease the performance, and the engine could even stop due to fuel starvation (FAA, 2016,b).

Thunderstorm. One of the most hazardous conditions an aircraft can come across is a thunderstorm, which is produced by the convection process.

Thunderstorms pass through three different stages before disintegrating. It is difficult to fly over the thunderstorms in aircraft that are less weight, and a better way to avoid the hazardous effect of thunderstorms is to fly around it (FAA, 2016b). The hazardous effects of thunderstorms are low visibility, turbulence, lightning, tornadoes, heavy rain, hail, surface wind shear, icing, runway contamination, microburst, and downburst (FAA, 2016a). Lightning might cause malfunctioning of electrical systems, temporary pilot blindness, and fuel ignition (Fultz & Ashley, 2016). These hazardous effects could lead to a loss of control, and damage the aircraft causing fatalities.

Turbulence. Lester (2007) defined turbulence as the bumpiness of an aircraft. It is the irregular movement of air that occurs due to vertical currents and eddies. It is unpredictable and is classified into four types based on severity. Severe turbulence has abrupt changes in altitude (may change up to thirty meters) and a pilot could lose flight control quickly, and during extreme turbulence pilot's control is lost, and it could cause structural damage to the aircraft. Turbulence can also disrupt the ability of a pilot to read the instruments in a cockpit and can cause motion sickness among pilots (FAA, 2016b).

Precipitation. Precipitation refers to water particles that are released from clouds and reach the surface of the earth due to gravity (Lester, 2007). Though precipitation cause a smaller number of general aviation accidents, it does pose a high risk as it affects safety (FAA, 2016a; FAA, 2016b). Rain reduces visibility, affects the accuracy of instruments, affects runway surface, which in turn have negative impacts on both landing and take-off of aircraft, larger ingestions of water could cause engine flameout, affect aircraft engines, water droplets that accumulate of the surface of wings can increase aircraft mass, and could even contribute to water in fuel tanks (Cao, Wu, & Xu, 2014; FAA, 2016a). Thus rain adversely affects the aerodynamic performance and is considered a threat to flight safety.

Inadequate weather training. As weather is a major contributor to GA accidents it is essential to know how weather training affects GA pilot's decision-making skills. Due to the development in technology and resources, it is essential for pilots to understand the new weather-related products (Lanicci et al., 2012). Pilots can collect the required information of weather from different sources such as Flight Service Station, Direct User Access Terminal Service - DUAT, Hazardous Inflight Weather Advisory Service - HIWAS) (Lanicci et al., 2012). Trained pilots who have experience in flying through different weather conditions can make effective decisions. Pilots without enough experience and training with the latest weather technology products will face more challenges in making hazardous weather decisions.

Previous research provides examples for GA pilots' lack of weather knowledge, new weather products, making new weather sources, the lack of education and training (Blickensderfer & Lanicci, 2014; Blickensderfer et al., 2015;

Cobbett, NTSB, 2014; Lanicci et al., 2012; Shappell & Wiegmann, 2017). These studies highlighted the lack of understanding about the NextGen weather products (NEXRAD) and indicated the necessity to train GA pilots about using the NEXRAD products more efficiently and effectively (Cobbett et al., 2014).

To understand the pilots' perspective of flying in adverse weather conditions, Lanicci et al. (2012) carried out a research study involving GA pilots who have experienced near-miss hazardous weather encounters. This research revealed the lack of weather knowledge and awareness of the associated severity of weather hazards were the main cause as to why GA pilots made hazardous weather decisions. This study also indicated that there was an inconsistency of weather information from different weather products available to pilots (Lanicci et al., 2012). For example, the information from METARs might indicate a fair weather condition but TAFs might indicate an IMC. When there are inconsistency pilots have to collect the required information from other sources, but if they lack weather knowledge and experience, they will miss the critical information and will take the necessary steps to avoid the situation.

The FAA's Weather Technology in the Cockpit (WTIC) program is NextGen's weather research program. It comprises of research projects in the Partnership to Enhance General Aviation Safety, Accessibility, and Sustainability (PEGASAS) (Johnson et al., 2017). It has identified various gaps that exist among GA pilots. They are skill, knowledge, ability, training, assessment, technology and information presentation gaps. Skill gaps include the gap in skills related to VFR into IMC decision-making, lack of situational awareness about VFR into IMC, and retaining weather knowledge. Knowledge gaps refer to the lack of insufficient training or the limited opportunity to fly in different weather situations during training (training gap), and little knowledge about the cockpit technology and its limitations (Johnson et al., 2017). Ability gaps will include a lack of ability to correlate, interpret, and apply weather information to weather factors such as the low ceiling, icing, fog, turbulence, precipitation, and wind. Assessment gaps, especially where there is no specific guidance regarding weather assessment examination (Johnson et al., 2017); for example, even if the applicants fail all the weather-related questions they can still get the certification. Technology gaps refer to the lack of awareness about the difference in the software application, mobile apps, differences in assessing the severity, and the potential impact of weather hazards negatively affecting the planning task. The available devices and simulators do not provide NEXRAD information.

Research Method

As the aviation-related accidents are reported to the NTSB, the database is searched for all the weather-related accidents that occurred between January 1, 1982, and December 30, 2015, in the U.S. The variables for this research study are

FAR Part 91 operations, Part 121 operations, weather-related accidents, fatal crashes, probable causes, and different injury level. The sample was limited to the submitted final reports of weather-related accidents. A mixed methodology i.e., both quantitative and qualitative methodology is used in this study. This research study used a descriptive nonexperimental research design especially integrating quantitative data (Creswell & Creswell, 2018).

Research Questions and Selection of statistical tests

The following research questions that guide this research study were addressed by testing various null hypotheses.

Research Question (RQ) 1: Do weather-related accidents cause more fatalities in general aviation operations?

RQ 2: Which weather hazard is the major contributor to the weather-related fatalities in general aviation accidents?

The selected data didn't meet the assumptions of parametric tests. Therefore, non –parametric tests (Chi-square test – Test for independence) were carried out using the online software package Stat Crunch. For all the statistical tests an alpha level of .05 significance is used.

Results and Discussion

Overview of Weather-related Accidents in the U.S. among Part 91 and Part 121 Operations

The search carried out in the NTSB aviation accident and incident database identified a total of 22,197 weather-related accidents that occurred in the United States between January 1, 1982, and December 31, 2015. Out of these accidents, 21,596 events (97.3%) occurred in Part 91 operations, and 601 events (2.7%) were from Part 121 operations (Table 1).

Table 1

Overall Number of Aviation Accidents that Occurred due to Different Weather Hazards in the US \across Part 91 and Part 121 Operations (1982 - 2015)

	Specific operations	
Weather hazards	Part 91	Part 121
High density altitude	722	0
Wind	14173	155
Icing	2273	27
Carburettor Icing	1166	0
Precipitation	691	43
Thunderstorm	518	60
Turbulence	2053	316

The accident rate (percentage) of weather-related accidents for the study period is depicted in Figure1. The percentage of events that occurred in Part 121 aircraft due to wind and icing is negligible and there were no events in the high-density altitude and carburetor icing categories. While the accident rate due to turbulence was high (13.3%) which was followed by the thunderstorm (10.4%) and precipitation (5.9%). Regarding Part 91 operations, the accident rate across all the weather hazards are above eighty-five percentage (85%). It clearly illustrates that the number of accidents and incidents that occurred due to all the weather hazards were higher among Part 91 operations than the Part 121 operations. A Chi-square test for independence ($p < .001$) indicated that the general aviation (GA) operations significantly exhibit a higher accident rate than the air carrier operations.

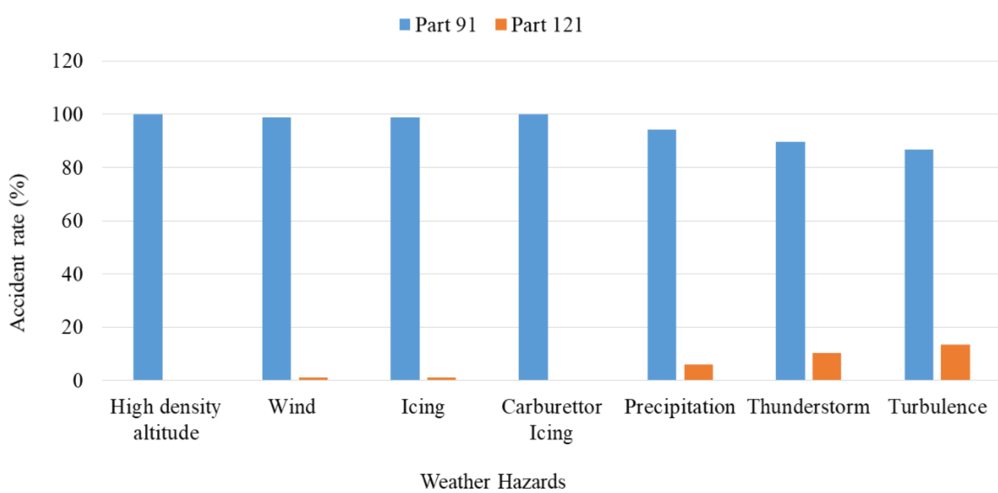

Figure 1. Weather-related Accidents that Occurred in the U.S. across Part 91 and Part 121 Operations (1982 - 2015)

During the study period in the US, weather was identified as a cause or contributing factor for 21,596 general aviation accidents (Table 1). FAA also reported that from 2003 to 2007, the weather was a major contributor in twenty percent of all Part 91 accidents (FAA, 2010, p. 29). Also, over a 32-year period (1982 to 2013), "weather was identified as a significant cause for 15,439 GA accidents, which contributed to twenty-five percent of accidents" (Fultz & Ashley, 2016, p. 296).

Weather-related Accidents in Part 91 General Aviation Operations

The current research revealed that Part 91 general aviation aircraft are more prone to weather-related issues with a total of 21,596 accidents with final reports. The number of weather-related accidents that occurred among the Part 91 operations is depicted in Figure2 on a yearly basis with the trend line for wind-related accidents.

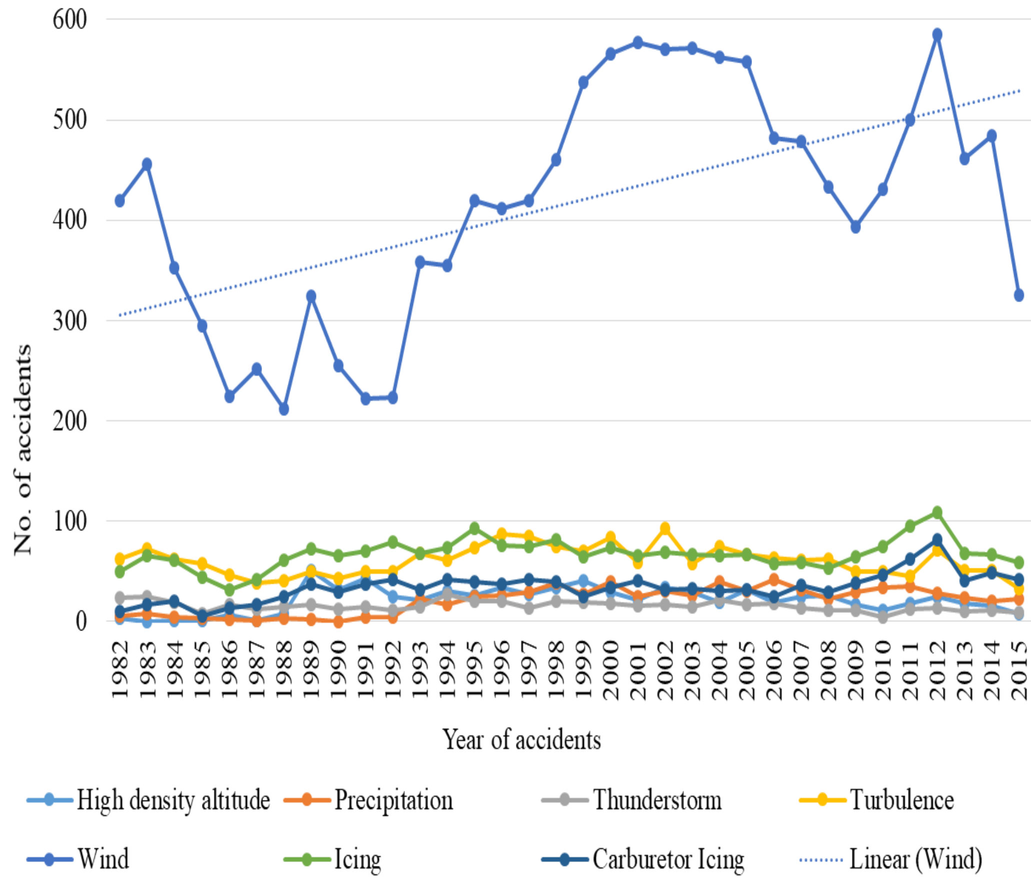

Figure 2. Weather-related Accidents that Occurred in Part 91 Operations in the U.S. (1982 - 2015)

Among the weather-related hazards, the major contributor to general aviation accidents is wind. The hazardous weather condition icing exhibited an increasing trend while turbulence conditions didn't exhibit any major change in the trend line during the study period. The carburetor icing exhibited an increasing trend from 1982 (10 accidents) to 2015 (42 accidents). The hazard, high-density altitude generally showed an increasing trend which is gradual, but from 2012 there was a decrease in the number of accidents.

The number of accidents that occurred due to precipitation hazards was less than seven per year for the first ten years of the study period i.e., 1982 to 1992 and it didn't show much variation. The hazardous condition thunderstorm exhibited a decreasing trend from 1982 to 1985, then an alternative trend till 1993, and then increased sharply to twenty-seven accidents in 1994. After that, it gradually decreased to 13 accidents in 1997 and was fluctuating slightly around that number for the next six years, and then it dropped slowly and caused 9 accidents in 2015.

Different Injury Levels that Occurred in Part 91 Accidents

The details of the different levels of injuries that occurred in Part 91 operations between 1982 and 2015 due to different weather hazards are provided in Table 2 and Figure3.

Apart from wind, the second major contributor for the weather-related accident is the icing condition, which has caused 2273 accidents so far and this is followed by other weather hazards such as turbulence (2053 accidents), carburetor icing (1166 accidents), high-density altitude (722 accidents), precipitation (691 accidents), and thunderstorm (518 accidents).

Table 2

Weather-Related Accidents of Part 91 Aircraft that Resulted in Different Injury Levels in the US (1982 to 2015)

Weather Hazards	Injury Level				
	Fatal	Serious	Minor	No injury	Total
High density altitude	186	136	136	264	722
Icing	809	255	390	819	2273
Carburettor Icing	124	169	296	577	1166
Precipitation	553	29	33	76	691
Thunderstorm	311	36	38	133	518
Turbulence	855	234	238	726	2053
Wind	3795	1464	1761	7153	14173

The icing was the second common cause of weather-related accidents, which caused a total of 2273 accidents (10.5%) during the study period and similar to the previous studies. Among these accidents, 35.59% were fatal, 11.22% accidents with serious injuries, 17.16% with minor injuries, and 36.03% accidents didn't cause any injuries. Fultz & Ashley (2016) reported that "icing contributed to fifty percent accidents in this category and structural icing is associated with eight percent of fatal weather-related accidents" (Fultz & Ashley, 2016, p. 300). From 1994 to 2003, icing caused seven percent of accidents among Part 91 operations (Sinclair, n.d., p. 7).

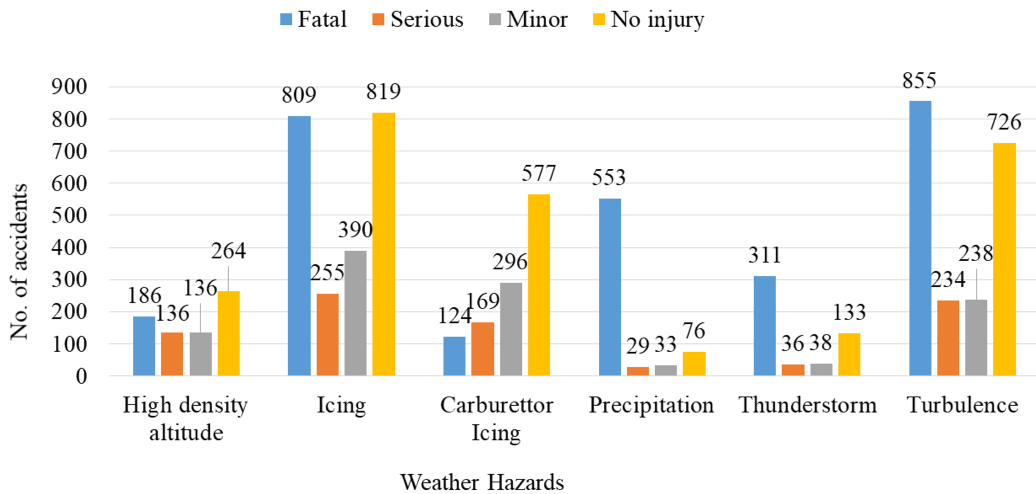

Figure 3. Weather-related Accidents of Part 91 Aircraft that Resulted in Different Injury Levels in the U.S. (1982-2015)

Turbulence caused 41.65% fatal accidents i.e., 2053 accidents. The accidents with serious and minor injuries were more or less equal i.e., 11.4% and 11.6% respectively and 35.36% of accidents didn't cause any injury. This result confirms the results of other studies which was conducted earlier. From 1982 to 2013, "turbulence contributed to forty-eight percent of fatal accidents" (Fultz & Ashley, 2016, p. 300).

The hazardous condition carburetor icing caused 10.63% fatal accidents while accidents with serious and minor injury levels were 14.49% and 25.39% respectively. About 49.49% of accidents were without any injuries. "Carburetor icing caused 34% accidents during a thirty-two year study period" (Fultz & Ashley, 2016, p. 300). FAA determined that the carburetor icing accidents trend was comparatively steady with an average of 17.2 accidents per year (FAA, 2010, p.12).

Among the high-density altitude accidents, 25.76% were fatal in the present study while "between 1982 and 2013 it contributed to 42 percent of accidents" (Fultz & Ashley, 2016, p. 300). FAA ranked high-density altitude as the third major weather hazards (108 citations) in part 91 operations (FAA, 2010). The present study also revealed that serious and minor injury levels were equal i.e., 18.84% each and 36.57% of accidents were without any injuries.

The precipitation weather hazard caused 691 accidents in total during the study period and 80.03% were fatal. The accidents without any injury were 11%, and those with serious and minor injuries were 4.2% and 4.78% respectively. Precipitation accounted for 27%of accidents and identified as a major hazard and associated with 71% of fatalities that occurred in GA accidents (Fultz & Ashley, 2016, p. 300).

In the present study, the thunderstorm condition caused 60.04% fatal accidents and 25.68 accidents were without any injuries. The accidents with serious and minor injury levels were 6.95% and 7.34% respectively. Thunderstorms were recognized as a cause in 69% of fatal accidents and were attributed to less than eight percent of all weather-related fatalities that occurred during 1982 and 2013 (Fultz & Ashley, 2016, p. 300).

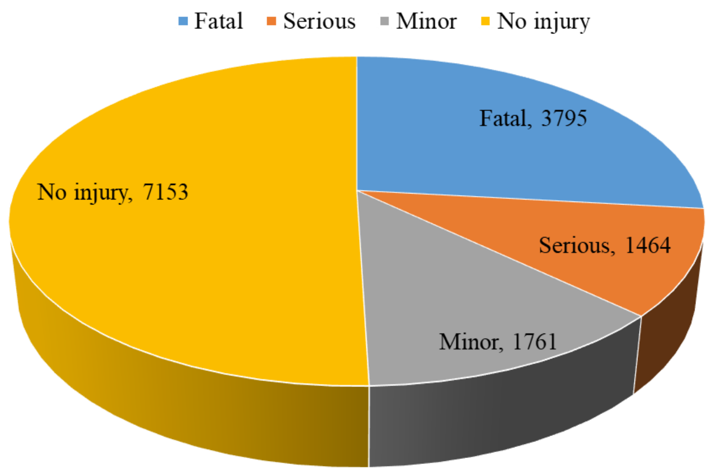

Figure 4. Weather-related Accidents of Part 91 Aircraft that Resulted in Different Injury Levels in the U.S. (1982 - 2015) Due to Adverse Wind

The present study identified wind as a significant weather hazard in Part 91 operations and it was associated with 14,173 weather-related accidents. Wind hazard exhibited an increasing trend (Table 2, Figure 3). Out of these accidents, 50.5% (7153) were without any injuries, 26.8% (3795) were fatal accidents, 10.3% caused serious injuries (1464), and 12.4% accidents (1761) resulted in minor injuries (Figure 4). The Chi-square test for independence ($p < 0.05$) showed that wind is a significant contributor to weather-related accidents in Part 91 operations.

Wind contributed to 65.6% of accidents among Part 91 operations. When it is compared to overall weather-related accidents i.e., considering all weather hazards that caused accidents in Part 91 operations, wind-related fatal accidents accounted for 17.6% (Table 2). The results were similar to the previous research conducted by FAA (2010), Fultz & Ashley (2016), and Sinclair (n.d.). FAA reported that "wind was the major contributor in 53.4% weather-related accidents and the number of accidents occurred due to gusts (33.8%), crosswind (33.5%), and tailwind (18.4%) during 2003 and 2007" (FAA, 2010, p. 32). "Wind contributed to

8,809 of the weather-related accidents from 1982 through 2013 and overall, wind contributed to more than fifty percent (50%) of weather-related accidents" (Fultz & Ashley, 2016, p. 296). Generally, wind-related accidents occur during take-offs and landings, when the aircraft is flying at a lower altitude and at low speed. So, it causes fewer fatalities (Capobianco & Lee, 2001). This was in contradiction to the present study, and the previous studies carried out by both FAA (2010), and Fultz and Ashley (2016) in which wind was identified as the major cause for fatal accidents in GA accidents.

There were "3,972 fatal weather-related accidents from 1982 and 2013" (Fultz & Ashley, 2016, p. 296) and the present study revealed 6633 fatal weather-related accidents during 1982 and 2015 (Table 1). During this 34-year period, weather contributed to 30.71% fatal accidents in GA operation (Table 2). The results of the present research revealed that carburetor icing caused 5.4%, precipitation caused 3.2%, high-density altitude caused 3.3%, and thunderstorm caused 2.4% of accidents. This is less when compared with the accidents that occurred due to wind (65.6%), icing (10.5%), and turbulence (9.5%). The lower fatalities that occurred due to carburetor icing, high-density altitude, precipitation, and thunderstorms, suggest that pilots are better trained of the threat and dangers posed by these weather hazards to aviation safety. Due to this preparedness, they are flying safely in these hazardous conditions (Capobianco & Lee, 2001; FAA, 2010). The previous research studies and the results of the present study suggest that aviation accident mitigation efforts should continue to focus more on educating and training pilots about the risk factors of weather.

The difference in accident rates identified between general aviation and air carrier reveals that pilots exhibit different characteristics related to pilot training and procedures involved. Air carriers are flown by a two-pilot team and it exhibited a low symptomatic casual factor occurrence and low accident rate when compared with Part 91 operations which are operated by a single pilot. The judgment of environmental conditions solely depends on GA pilot's individual experience whereas air carrier pilots can make decisions as a team based on their experiences. The effect of latent factors such as physical and mental status, environment, and equipment failure on GA pilots' judgment has to be considered in developing mitigation strategies as it could lead to fatal or serious accidents. Violations i.e., intentionally breaking the rules and instructions could also cause fatal or serious accidents. "The demonstrated ability of general aviation pilots to cope with equipment failure may indicate that their technical training is sufficient, while the increased potentiality, when faced with environmental changes could indicate a lack of experience under adverse flight conditions" (Erjavac et al., 2018, p. 162). Reducing the skill-based errors is the most efficient way to reduce the rate of accidents in the aviation industry. It is evident that the pilot's good judgment and decision-making skill is essential for reducing fatal accidents (Hunter, 2006;

O'Hare, 1992). The previous research studies also showed that formal training related to the utilization of weather-related equipment was very rare during the pilot training programs. Therefore, the pilot applicants lack the skills to apply weather knowledge in making effective decisions during the actual flight (Shappell & Wiegmann, 2003, 2017). Thus, these studies clearly demonstrate further research is essential to scrutinize the lack of aviation weather –related knowledge, education, training, and skills.

Weather Technology-in Cockpit

The Weather Technology available in the Cockpit (WTIC) are Meteorological Report (METAR)/Terminal Aerodrome Forecast (TAF), Pilot Reports (PIREPs), Significant Meteorological Information (SIGMETs), Airmen's Meteorological Information (AIRMETs), weather radar maps, icing maps, adjacent traffic, lighting, ceiling, and visibility graphs, and Notices to Airmen (NOTAMs).

METAR provides information about actual weather at the time of its issue while TAF is a weather forecast. It is prepared by a meteorologist based on weather observations and other meteorological tools that model the weather so that the forecaster can generate a weather forecast. TAF is only for a short distance around an airport. TAF includes information related to wind, cloud coverage, precipitation, and even some wind shear between levels lower in the airport environment. PIREPs are prepared by pilots based on the actual weather conditions they come across while in flight. Traditionally, these reports are transmitted through radios to ground stations, but now appropriately well-equipped aircraft can send reports using the Aircraft Meteorological Data Relay (AMDAR) program. SIGMETs are issued for severe icing and severe turbulence, dust storms that cause low visibility and for volcanic ash conditions. AIRMETs are issued for mountain obscuration, Instrument Flight Rule conditions, moderate turbulence, icing, and freezing levels. These technologies help pilots to make better decisions during hazardous weather conditions and enhance flight safety.

The national airspace system is developing the Next Generation Air Transportation System (NextGen), which includes new technologies, such as the Automatic Dependent Surveillance-Broadcast (ADS-B), Flight Information System Broadcast (FIS-B), Automation, Traffic Information Services – Broadcast (TIS-B), Data Communications, Decision Support Systems (DSS), Performance Based Navigation (PBN), System Wide Information Management (SWIM), and Next Generation Weather Radar (NEXRAD) system.

FIS-B and TIS-B gather the information through ADS-B ground stations and provide the information, through a datalink to the cockpit. The ADS-B receiver in the aircraft interprets the data and displays it on a screen in the cockpit. FIS-B is developed for general aviation pilots, and to use this system, the aircraft should be equipped with both ADS-B in and out systems. FIS-B provides services such as METARs, TAFs, AIRMETs, SIGMETs, PIREPs, NOTAMs, and NEXRAD precipitation maps. The data provided by NEXRAD is at least five minutes old and is not in real-time. The idea is to compare the radar reflectivity of precipitation and its associated turbulence level with a specific color in the NEXTRAD image. This approach will help the pilots to avoid turbulence. Pilots can use the NEXRAD image along with their flight plan and strategically plan their weather deviation and collaborate with ATC at an earlier time on a re-route.

Recommendations

The research team provides the following recommendations based on the results of the present study.

Education and Training of Weather Technology

There are numerous weather products available for pilots as mentioned above, and each has its own merits and demerits. Additionally, some of the pilots do not know how to read the current METAR and TAF formats. To read NOTAMS pilots should be familiarized with decoding the information, and to disseminate the PIREP report, pilots should memorize and be able to remember the symbols displayed on the PIREP map. Pilots using NextGen products should be aware of the fact that the data displayed in the cockpit is not in real-time. They should also be able to read the radar color palette. An awareness and training of these products in real-time is recommended for general aviation pilots. So that they can use this information during different flight phases to make better decisions.

Examination Requirements

Another critical finding is the FAA written exam requirements for private pilots. Currently, even if they fail in weather-related section they can still pass and receive pilot certification. This should be changed and examinees should be mandated to pass weather-related questions to get FAA certification. Further, the written examination should include questions based on topics such as VFR into IMC conditions, aviation weather forecasts, weather service information, cloud information, precipitation, and many more. A fair understanding of these topics is essential for the weather decision-making process. This should be implemented significantly as it will contribute to aviation safety.

Simulation/ Virtual Reality-based Training with Different Weather Hazards

The use of a full flight simulator (FFS) is an innovative approach as it uses advanced technology in areas of motion, visuals, communication, and air traffic. Virtual reality is a new technology that uses headsets or multi-projected environments to simulate a user's physical presence in a virtual environment. It has the ability to transmit vibrations and other sensations to the user. This technology can be used for both initial and recurrent training programs. As it is not possible to train pilots for each and every weather in a real-life scenario, virtual reality seems to be the best alternate solution. Using this advanced technology, pilots can be exposed to adverse weather hazards such as wind, thunderstorms, turbulence, icing, precipitation, and be well trained as it is a good tool.

Conclusions

General aviation is a complex system and accidents occur due to different hazardous weather conditions. This study identified the major weather hazards associated with GA accidents as high-density altitude, icing, carburetor icing, turbulence, thunderstorms, wind, and precipitation. After examining the accidents that occurred in GA industry during a 35-year period the statistical analysis of this study concluded wind as the major weather hazard. Knowledge and a good understanding of wind conditions that predominantly cause GA accidents will provide required information to pilots that can be used during an actual flight.

Though general aviation accidents have decreased during the study period, it still continues and poses a threat. Future researchers should consider investigating whether there is any relationship between El Nino effect and different weather hazards, if there is a relationship what is the intensity of its impact on weather hazards and eventually on GA aircraft, how frequently do the performance-based errors occur, how many are memory failures and how many are attention failures, how many violations do occur, what is the relationship between these different factors, which type of error occurs first, and which factors occur as consequence. In short, what are the exact type of errors that occur in each category? This type of future research will help to further reduce the GA accident rate and increase aviation safety. Regardless, the results of this study highlight the necessity to train the current and new GA pilots on new weather products to reduce the accidents and fatalities in GA operations.

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