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Evaluating Crew Resource Management (CRM) and Single-Pilot Resource Management (SRM) in Aviation

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Abstract

Objective: This paper aimed to showcase the safety advancements achieved in both commercial aviation and general aviation by presenting accident and fatality data from 2000 to 2019. The primary objective was to unveil the influence of Crew Resource Management (CRM) in commercial aviation by examining its implementation process and contrasting it with Single-Pilot Resource Management (SRM) in general aviation, with the goal of determining a more effective approach for implementing SRM.
Background: Despite several efforts made in the last decade, general aviation still accounts for 94% of civil aviation accidents. In 2018, a slight increase in GA accidents was recorded compared to the previous year (2017). For this reason, general aviation safety has become a significant concern for the aviation industry. Therefore, it is important to evaluate the impact of CRM and SRM.
Methodology: A mixed-methods research design was used for this study. It is particularly valuable for showcasing the safety advancements achieved in both commercial aviation and general aviation. The data were collected from the report generated by the National Transportation Safety Board (NTSB) and advisory circular 120-51E.
Results: The analysis of the data revealed that CRM has played a critical role in mitigating human errors and enhancing flight safety in commercial aviation, and its effectiveness can be linked to the components and fundamentals of CRM training implementation. However, its counterpart, SRM, hasn't produced significant results in general aviation compared to CRM.
Conclusions: Analysis of commercial aviation accident data from 2000 to 2019 revealed that CRM training has produced the desired outcomes, mitigated human error and improved safety. On the other hand, SRM has not been as effective compared to CRM in mitigating human errors and enhancing flight safety. Further investigation revealed that a lack of consistent and monitored human factors awareness training in GA might have contributed to the lower effectiveness of SRM. Therefore, an effective approach to implementing SRM will involve incorporating consistent and monitored human factors awareness training as part of SRM training.

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General aviation (GA) is used to describe all civilian aviation operations apart from operations involving paid passenger or cargo transport (Boyd, 2017). Research revealed that more than 90 percent of the roughly 220,000 civil aircraft registered in the United States are GA aircraft, and more than 80 percent of the certified pilots in the United States fly GA aircraft (AOPA, 2019). General aviation (GA) pilots form a highly diverse group. They differ in terms of training, age, total flight experience, recency of experience, motivation, flight skills, basic abilities, the amount of supervision they receive, and various other parameters (Shelnutt et al., 1980). This diversity can be seen as one of the factors contributing to safety issues in the GA community.

GA safety has been a significant concern due to a high number of fatalities. In an attempt to tackle safety concerns in the general aviation community, several efforts have been made in the last decade. For instance, the General Aviation Joint Safety Committee (GAJSC) (*formerly the General Aviation Joint Steering Committee*) was launched in 1997 as part of the industry-government Safer Skies Initiative to improve aviation safety through data-driven risk reduction efforts focused on education, training, and enabling new equipment in GA aircraft (GAJSC, 2023). However, little or no improvement is recorded in terms of the number of accidents and incidents. In 2018, a slight increase in GA accidents was recorded compared to the previous year (2017). For this reason, general aviation safety has become a great concern to the aviation industry.

Due to the importance of flight safety, in 1979, the National Aeronautics and Space Administration (NASA) organized a conference where the human error aspects of most air crashes were identified as failures in interpersonal communication, decision-making, and leadership (Helmreich et al., 1999). This led to the evolution of cockpit resource management, which was first initiated by United Airlines in 1981. The program focused on correcting deficiencies in individual behavior, such as a lack of assertiveness by juniors and authoritarian behavior by captains' leadership (Helmreich et al., 1999). This marked the first generation of crew resource management (CRM). The second generation evolved after another conference NASA organized in 1986, which changed the name from cockpit resource management to crew resource management (CRM). The third and fourth generations evolved as the scope of CRM became broader, and necessary safety improvements were recorded in commercial aviation (Helmreich et al., 1999).

In an attempt to enhance general aviation safety, single-pilot resource management (SRM), which is an adaptation of crew resource management (CRM) training to single-pilot operations, was first introduced by the National Business Aviation Association (NBAA) in 2005 by publishing training guidelines for single-pilot operations of very light jets (VLJs) (Kearns, 2011). SRM is the art of managing all onboard and outside resources available to a pilot before and during a flight to help ensure a safe and successful outcome, thereby reducing the number of aviation accidents caused by human error (Im et al., 2021). While traditional Crew Resource Management (CRM) is designed for multi-crew environments, SRM recognizes the unique challenges faced in single-pilot operations and emphasizes the importance of aeronautical decision-making (ADM), risk management (RM), task management (TM), automation management (AM), controlled flight into terrain (CFIT) awareness, and situational awareness (SA) in ensuring safe and effective flight operations (Idowu et al., 2023).

The ability to prioritize tasks and select the most appropriate course of action is crucial for ensuring flight safety (Idowu, 2021). As a result, the concept of SRM ensures that single pilots constantly assess the situation, evaluate options, and make timely and sound decisions (Kearns, 2011). These decisions range from route planning, weather, diversions, handling in-flight emergencies, and overall workload management. Effective workload management in SRM involves recognizing and mitigating factors that could lead to cognitive overload, allowing the pilot to maintain focus and make informed decisions. The workload in single-pilot operations includes navigation, communication, systems monitoring, flying the aircraft, and responding to unforeseen events (Kanki et al., 2019). Unlike multi-crew environments where tasks can be distributed among team members, these tasks are being handled by just one pilot (Im et al., 2021).

Ultimately, SRM emphasizes the importance of the five Ps: the plan, plane, pilot, passengers, and programming (Im et al., 2021). The plan addresses the basic elements of cross-country planning: weather, route, fuel, current publications, etc., and also includes all the events that surround the flight and allow the pilot to accomplish the mission (Im et al., 2021). The plane includes aircraft systems, equipment, airframe, avionics, and all that require the pilot's proficiency (Im et al., 2021). The third P, which stands for the pilot, addresses illness, medication, stress, alcohol, fatigue, and emotion to help a pilot identify and mitigate physiological hazards at all stages of the flight (Im et al., 2021). The fourth P, which stands for passengers, addresses the threats associated with passengers' needs, such as physiological discomfort, anxiety about the flight, or desire to reach the destination that can create potentially dangerous distractions (Im et al., 2021). The last P stands for programming, which refers to panel-mounted and handheld equipment. This set of equipment can reduce pilot workload and increase situational awareness. However, electronic equipment can lead to complacency and also create a serious distraction from other flight duties (Im et al., 2021).

Despite the implementation of SRM in general aviation to replicate the results of CRM, statistics show that general aviation suffers a higher fatal accident rate than scheduled airline flights (Min, 2018) and accounts for 94% of civil aviation fatalities (Boyd, 2017). This necessitates reviewing the impacts of CRM and the approach by which it is delivered and comparing it to the impact of SRM and the approach by which it is delivered to deduce the factors responsible for their effectiveness or ineffectiveness in terms of safety. The goal is to determine an effective approach for implementing SRM.

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Intent

This paper aimed to showcase the safety advancements achieved in both commercial aviation and general aviation by presenting accident and fatality data from 2000 to 2019. The primary objective was to unveil the influence of Crew Resource Management (CRM) in commercial aviation by examining its implementation process and contrasting it with Single-Pilot Resource Management (SRM) in general aviation, with the goal of determining a more effective approach for implementing SRM.

Research Questions

- What role does CRM play in mitigating human errors and enhancing flight safety in commercial aviation?

- How effective is single-pilot resource management's current implementation process in enhancing general aviation safety?
- What is an effective approach for implementing SRM?

A mixed-methods research design will be employed to answer these research questions. The quantitative aspect of the research will descriptively showcase the safety advancements achieved in both commercial aviation and general aviation, as well as the trends in accidents and fatalities recorded between 2000 and 2019. The qualitative aspect of the design will provide a deeper understanding of the context, enabling a comprehension of the effects of crew resource management and single-pilot resource management on commercial and general aviation, respectively.

Literature Review (Case Study Background)

The aviation industry has made tremendous strides since the first powered flight in 1903 in aircraft advancements and the development and evolution of human factors training. However, the general notion that flight training only consists of learning how to operate an aircraft vastly underestimates the depth of knowledge necessary for safe flight operations. Human factors are introduced in general aviation (GA) with single pilot resource management (SRM) and continue throughout commercial operations in crew resource management (CRM). While CRM has impacted the safety of commercial flights for the better, research suggests there is a deficiency in the effectiveness of SRM in GA.

Single pilot operations are naturally one of the most stressful task-demanding flights a pilot can encounter, as observed by Im et al. (2021). Thus, before a pilot can break away from the Earth's surface in an aircraft, they must receive the FAA-mandated ground school training complete with SRM lessons. SRM is the art and science of responsibly handling all the internal and external resources before and during a flight for safe operations (Im et al., 2021). Shank emphasizes that anything a pilot needs to complete a flight can be a resource, no matter how insignificant, like a pen and paper. Built-in aircraft systems like a generator and backup fuel pumps are resources available that are initially forgotten about (Shanks, 2014). "Nearly anything can be a resource, but nothing is a resource until you recognize it as such" (Shanks, 2014, p. 6).

Interestingly, Safety's (2021) study draws attention to the fact that the SRM training curriculum mainly focused on the five Ps (plan, plane, pilot, passengers, and programming) while borrowing from CRM concepts. Contributing Crew Resource Management Helmreich & Foushee (2019) state that the acceptance of training is ideal, but it has little indication of the effectiveness of said training if there are no behavioral tools to apply the concepts. The same point is valid concerning teaching pilots SRM practices. In other words, SRM has primarily been a trickled-down version of CRM without the proper channels teaching the technique in the practical field.

Robert Wright is an airline transport pilot (ATP) with over 10,000 hours formerly employed by the FAA who has expressed aversion towards the lack of risk management training up until recently. Through evidence of FAA publications and personal experience, Wright noted that the FAA and industry partners had vague instructions on performing, teaching, and testing risk management. The FAA Risk Management Handbook lacks a thorough explanation of identifying, assessing, and mitigating risks and does not deliver real-world case studies; it still is not updated since its publication in 2009. During Wright's proficiency checks, he requested a risk-based flight review that the General Aviation Joint Steering Committee (GAJSC) issued a

safety enhancement recommendation. Unfortunately, Wright's CFIs were unfamiliar with this approach or the advisory circular (AC) 61-98. Consequently, "The resulting flight reviews [he] received were desultory affairs, maneuver-based, unrelated to the missions [he] typically [flies] and utterly unchallenging" (Wright, 2020, p. 6). While Wright remains optimistic that the ACS is a step in the right direction for educating the GA community on risk management and decreasing the GA accident rate, plenty of work remains to be done.

Implementing crew resource management (CRM) has taken the aviation industry by storm with predominantly positive feedback and results. After several catastrophic aircraft accidents, the concept of CRM was developed to compel flight crews to maintain positive control of the aircraft no matter the situation. Most of these accidents were due to poor decision-making, loss of situational awareness, and an absence of leadership (Kanki et al., 2019). CRM combines technical skills and human factors in the flight environment. Embry- Riddle Aeronautical University's Frank J. Tullo, a pilot and flight operations manager, took a leaf from former FAA administrator Donald Engen, who stated accidents happen from crews rather than individual crewmembers by simplifying CRM into one word: teamwork. While a safe flight is recognized as the success of a team of employees- pilots, flight attendants, mechanics, dispatchers, fuelers, and ground crew- effectively working together for the same goal, the team for this discussion will focus on the crew members aboard the aircraft (Kanki et al., 2019). Tullo claims, "The true definition of "teamwork" or CRM is its focus on the proper response to threats to safety and the proper management of crew error" (Kanki et al., 2019, p. 55).

Research demonstrates that CRM has been a welcomed concept by the aviation industry and has a consistent positive influence (Kanki et al., 2019). The first step in introducing any new idea or concept in an industry is gathering feedback to determine the general census and the best course of action. Data was collected from over 20,000 flight crewmembers, both in civilian and military functions, from around the world. The results were wildly in favor of CRM along with advocacy for line-oriented flight training (LOFT), or "full mission simulation training" (Kanki et al., 2019, p. 25). When comparing the attitudes of crewmembers pre and post-training, there was a noticeable positive increase. For example, two United Airlines flights that ended in an accident had crews who acknowledged the impact CRM training had on them in Flight 811 and Flight 232 emergencies. Each crew worked effectively in the high-stress environment to reduce fatalities. According to the cockpit voice recorder, both crews managed to maintain positive communication and verification in urgent situations. Moreover, as more organizations incorporate CRM training, more crewmembers will comply with the new norms and standards of behavior.

CRM has transformed the aviation community and is continuously updated and enhanced to best serve aviation professionals in the ever-advancing flight deck. Contributing writer Linda Orlady of Crew Resource Management (2019) witnessed several airlines present their efforts to CRM and human factors. The airlines had similar aspects for their framework; however, no two airlines' CRM programs are identical. Each airline has a unique structured program for its culture and employees. Most importantly, the program receives support from the top management down to the flight line and vice versa. Helmreich's findings included that without recurrent CRM training, the results and benefits of CRM will deteriorate over time. Helmreich administered a cockpit management attitudes questionnaire (CMAQ) a year after one organization's initial CRM training, and the results were disappointing. The data revealed that attitudes returned to their baseline prior to CRM lessons. If long-term change is the goal of

CRM, it requires commitment and reinforcement to ensure the information is not 'brain dumped.' Furthermore, the airlines collaborated with the pilots to implement and review the training. The airlines are aware that CRM will always be a work in progress and should continually evolve to deliver the best training to employees (Kanki et al., 2019).

Operating an aircraft solo or as part of a crew is no easy feat, as it requires intensive training both in flight and on the ground. Flight training is further complicated when attempting to learn and know all the available resources. SRM and CRM are multidisciplinary subjects involving more than aviation but also how humans operate in the flight environment. Since the introduction of CRM to commercial aviation, the safety record has improved due to increased coordination of crewmembers. On the contrary, SRM struggles to provide the exact drastic change in GA accident rates compared to CRM in commercial flights. A contributing factor in the variable SRM and CRM accident rates is the level of development of training programs. Nevertheless, additional research is necessary to determine the effectiveness of both SRM and CRM due to limited research because most studies focus on evaluation rather than effectiveness (Kanki et al., 2019).

Methodology

A mixed-methods research design was used for this study because it fits the research questions properly. It is particularly valuable for showcasing the safety advancements achieved in both commercial aviation and general aviation. The quantitative aspect of the design was descriptive, providing graphical representations of accidents and fatalities in both commercial and general aviation from 2000 to 2019. The qualitative aspect offered a deeper understanding of the context to comprehend the effects of crew resource management and single-pilot resource management on commercial and general aviation, respectively, and to analyze the implementation process of crew resource management.

The data were collected from reports generated by the National Transportation Safety Board (NTSB) database. This database facilitates swift searching and grouping of data for subsequent analysis. The accident and fatality reports of U.S. commercial and general aviation accidents from 2000 to 2019 were collected and analyzed to determine the rate of accidents and fatalities in U.S. Part 121 operations and general aviation. This analysis aimed to identify the frequency of accidents and fatalities after CRM and SRM implementation to determine the impact of CRM training on commercial aviation and to compare it with the impact of SRM in general aviation. Further inquiry into the general aviation accident reports was conducted to determine accidents by flight purpose and aircraft category, identifying the type of general aviation flying with the highest fatalities. Additionally, data pertaining to the implementation of crew resource management were collected from Advisory Circular 120-51E and were analyzed using qualitative deductive coding.

Data Analysis

Since the goal of CRM and SRM is not to completely eradicate human errors but to mitigate them to reduce the number of accidents and fatalities, the analysis of the data was grouped into three sections (1) analysis of Part 121 accidents and fatalities, (2) analysis of general aviation accidents and fatalities, and (3) a thorough examination of advisory circular AC 120-51D to decipher the approach used in CRM training.

The first analysis focused on Part 121 operations, where we reviewed Part 121 accident reports over a period of 20 years (2000-2019) to determine how CRM training impacted flight safety. Afterward, we looked at the trends of accidents and fatalities and compared them with the number of flight hours flown yearly in Part 121 operations within those periods to descriptively determine the impact of CRM.

We gathered data on aviation accidents involving single-pilot operations over a period of 20 years (2000-2019) to assess how SRM principles have impacted general aviation safety. Afterward, we looked at the trends of accidents and fatalities and compared them with the number of flight hours flown yearly in general aviation within those periods to determine the impact of SRM descriptively. We also examined the categories of general aviation operations with the highest numbers of accidents and fatalities.

We reviewed the objectives and goals of CRM training implementation and components of CRM training in the advisory circular AC 120-51D through the coding process to determine the approach and scope of CRM training. The three components of CRM, which are (1) Initial Indoctrination /Awareness, (2) Recurrent Practice and Feedback, and (3) Continuing Reinforcement, were examined along with the six fundamentals of CRM training implementation.

Results

CRM was found to play a critical role in mitigating human errors and enhancing flight safety in commercial aviation. Since its implementation, our analysis of accidents and fatalities over a period of 20 years has shown an improvement in aviation safety. While this research did not explore the actual decision-making and resource management skills of CRM or SRM, it discovered that the improvement in commercial aviation safety could be linked to the effectiveness of CRM training in instilling these skills in flight crewmembers.

The analysis of part 121 accidents revealed that from 2000 to 2019, 32.9% of the accidents occurred between 2000 and 2005. 22.9% occurred between 2005 and 2009. 20.7% occurred between 2010 and 2014, and 23.5% occurred between 2015-2019. The main goal was to examine the trend of fatalities to deduce the impact of CRM. So, the analysis of the fatalities revealed that from 2000 to 2019, 82.1% of the fatalities occurred between 2000 and 2005. 15.9% occurred between 2005 and 2009. 1.4% occurred between 2010 and 2014, and 0.6% occurred between 2015-2019. Figures 1 and 2 show the graphical representation of the Part 121 accidents and fatalities from 2000 to 2019.

Figure 1: Part 121 Accidents and Fatalities Graph in five years intervals.

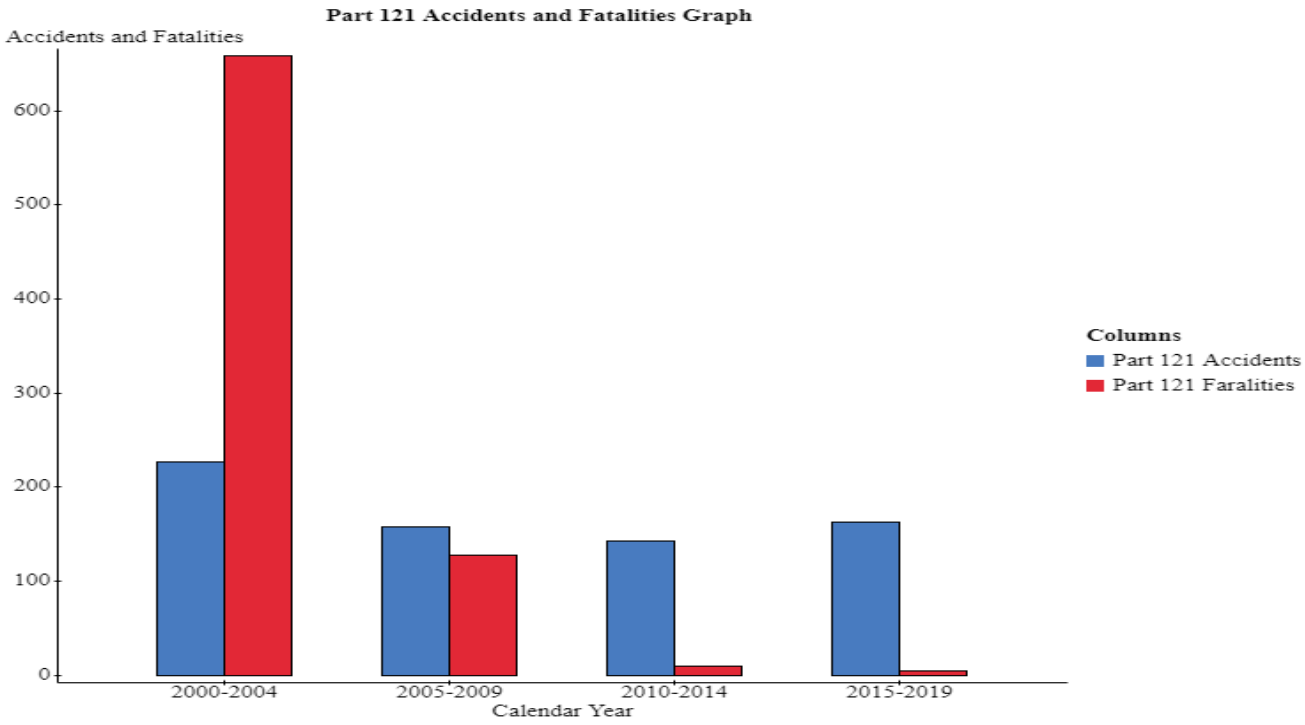
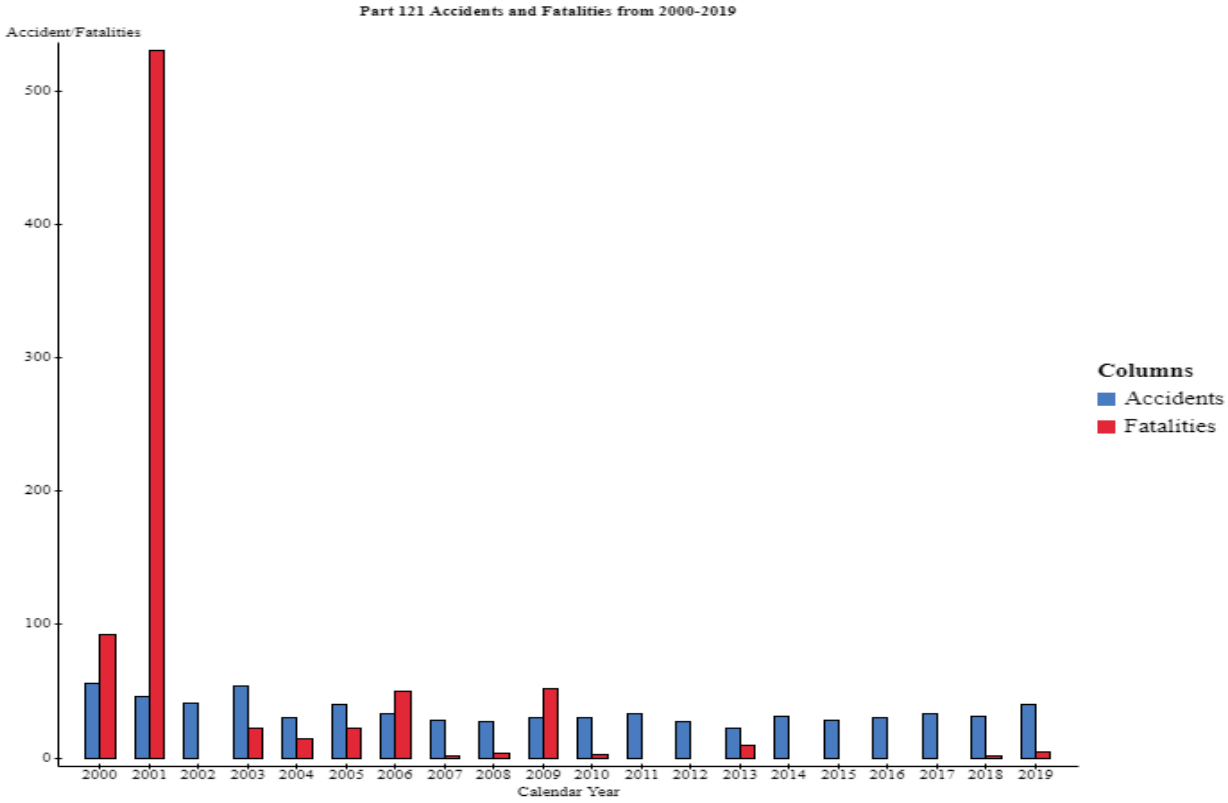


Figure 2: Yearly Part 121 Accidents and Fatalities Graph



Further analysis examined the number of flight hours in part 121 operations from 2000 to 2019. The analysis revealed that from 2000 to 2019, 24.4% of the Part 121 flight hours were

flown between 2000 and 2005, 25.9% between 2005 and 2009, 24.2% between 2010 and 2014, and 25.5% between 2015 and 2019. The highest number of flight hours was recorded between 2005 and 2009, followed by 2015 and 2019. This is represented in figures 3 and 4.

Figure 3: Part 121 Flight Hours from 2000-2019

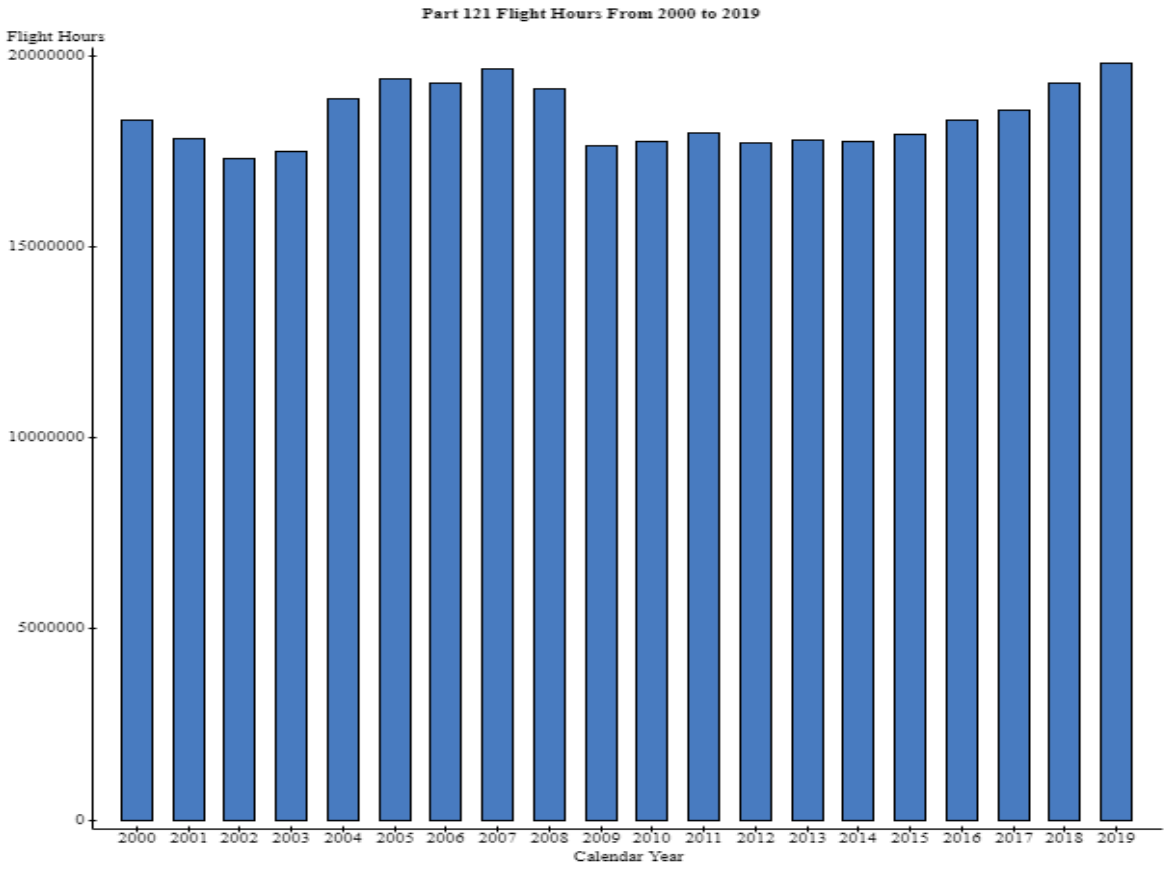
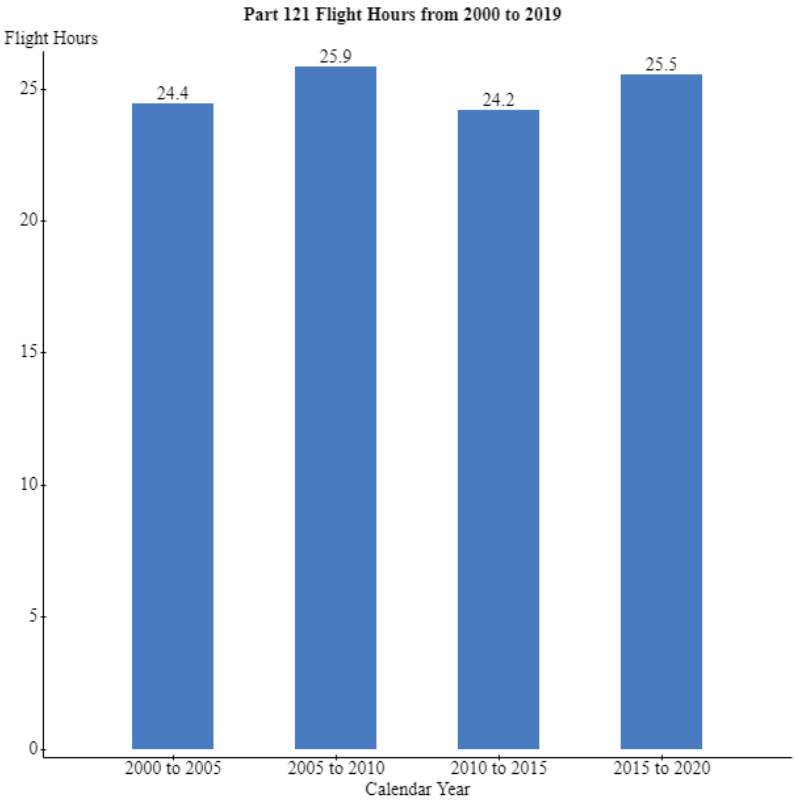


Figure 4: Percentage of Part 121 Flight Hours from 2000-2019 in five years intervals



The impact of SRM on general aviation safety has not been significant considering the analysis of accidents and fatalities from 2000 to 2019. Indeed, SRM was introduced in 2005 with the hope of helping pilots manage all available resources before and during a flight to ensure a safe and successful outcome, thereby reducing the number of aviation accidents caused by human error. The analysis revealed that no significant safety improvements were recorded in general aviation after 2005 considering the accident and fatality rates.

The analysis of general aviation accidents revealed that from 2000 to 2019, 29.2% of the accidents occurred between 2000 and 2005. 26.7% occurred between 2005 and 2009. 23.1% occurred between 2010 and 2014, and 21% occurred between 2015-2019. As earlier stated, the main goal was to examine the trend of fatalities to deduce the impact of SRM. So, the analysis of the fatalities revealed that from 2000 to 2019, 30.1% of the fatalities occurred between 2000 and 2005, 28.2% occurred between 2005 and 2009, 22.3% occurred between 2010 and 2014, and 19.4% occurred between 2015-2019. Figures 5 and 6 show the graphical representation of general aviation accidents and fatalities from 2000 to 2019.

Figure 5: General Aviation Accidents and Fatalities Graph in five years intervals

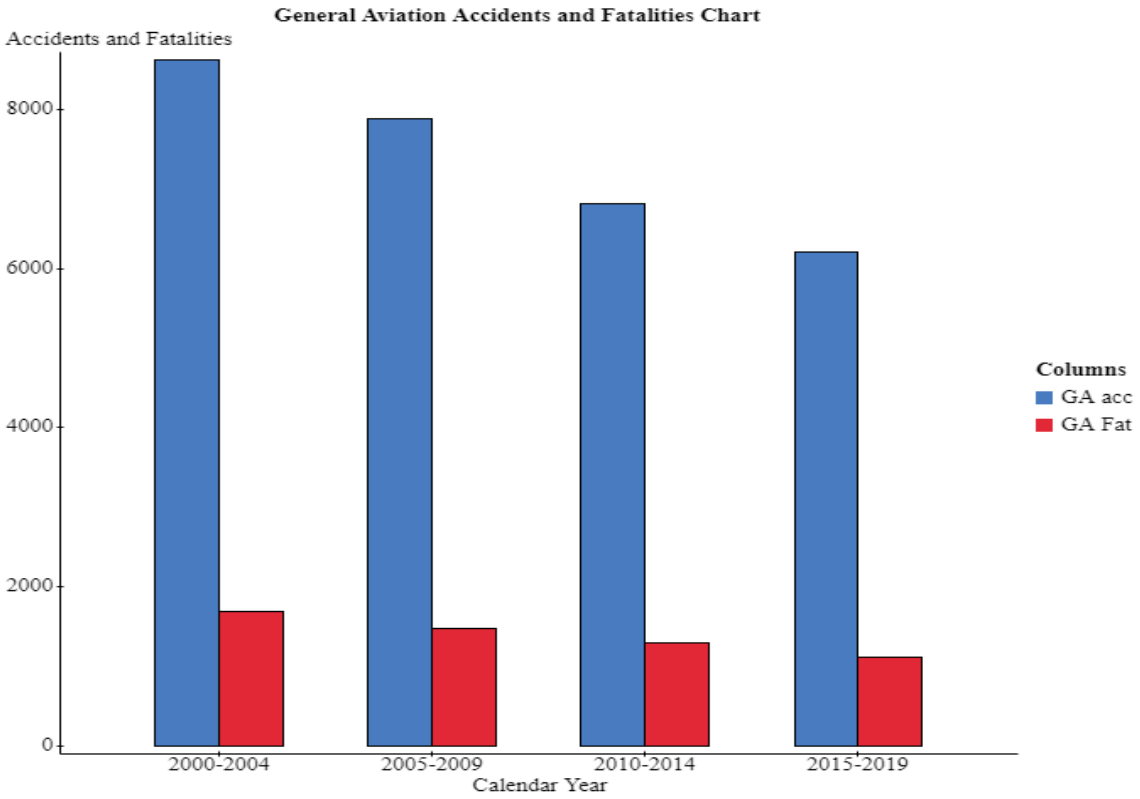
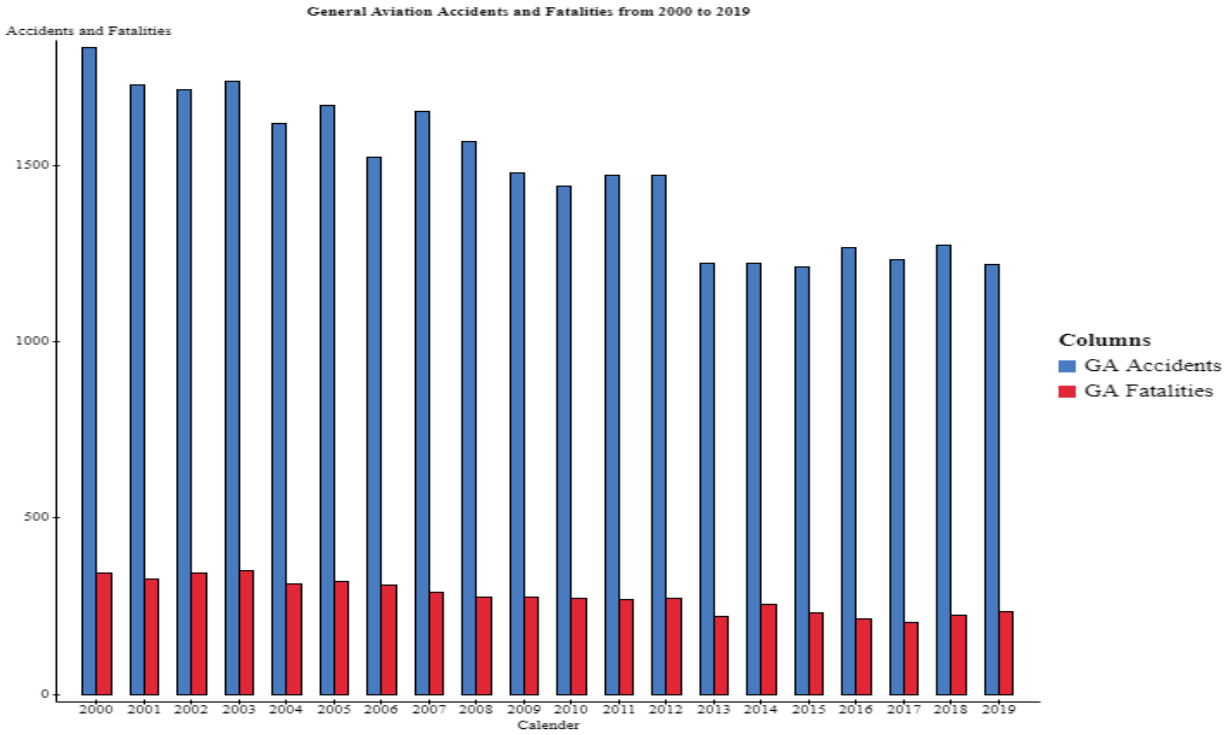


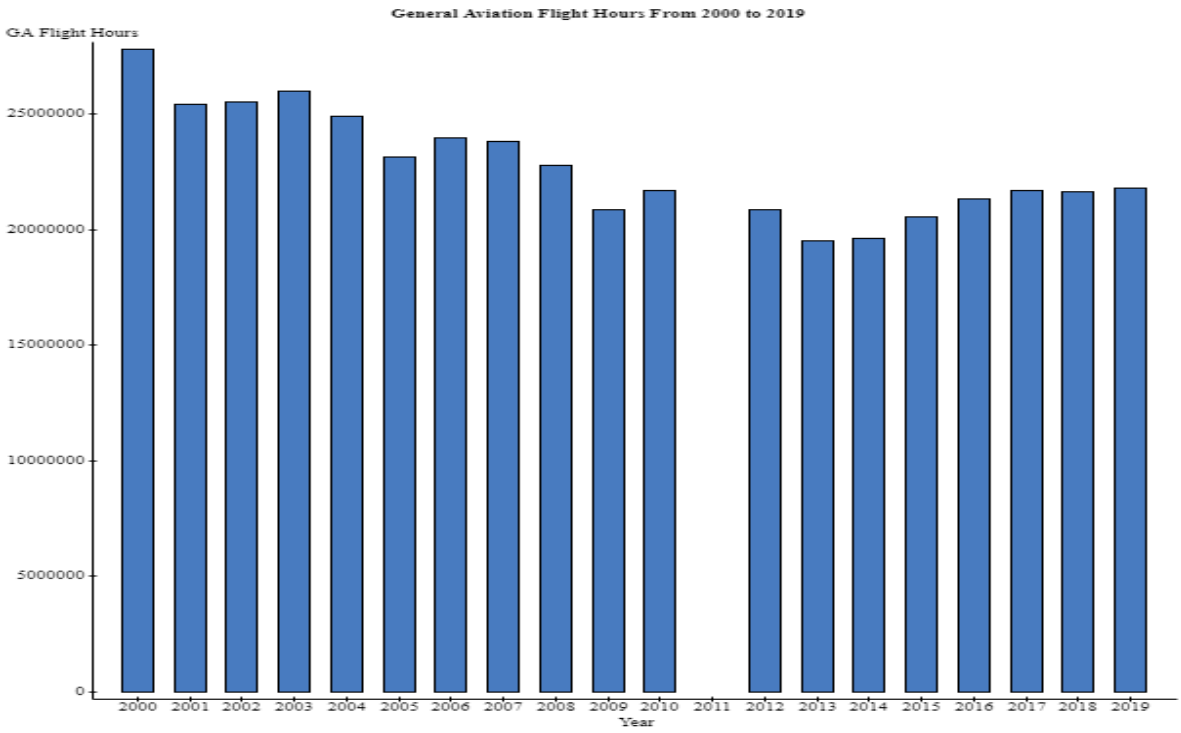
Figure 6: Yearly General Aviation Accidents and Fatalities Graph



The analyses of general aviation Accident and fatality rates showed a gradual decrease in accidents and fatalities. However, this metric cannot be used independently to deduce the

effectiveness of SRM. The analysis of general aviation flight hours showed a gradual decrease from 2000 to 2019. Unfortunately, we are unable to calculate the percentage in five years intervals because NTSB did not supply the data for hours flown in the year 2012. However, because of the discrepancy, we could calculate the flight hours by omitting the hours flown from 2010 to 2014. So, the hours flown from 2000 to 2004 are 129,698,000, from 2005 to 2009 is 114,615,830, and from 2015 to 2019 is 107,076,594. This confirms that there has been a gradual decrease in the number of hours flown in general aviation from 2000 to 2019. As a result, the gradual decrease in accident and fatality rates cannot be used to determine the effectiveness of SRM. This is represented in figure 7.

Figure 7: General Aviation Flight Hours from 2000 to 2019



There are many operations in general aviation. So, a closer look was taken to analyze the 2018 general aviation accidents and fatalities report. The data analysis showed that personal flying and instructional flying have the highest number of accidents in general aviation. Personal flying accounts for 69.77% of general aviation accidents, and instructional flying accounts for 15.52% of general aviation accidents.

Figure 8: General Aviation Accidents by flight purpose

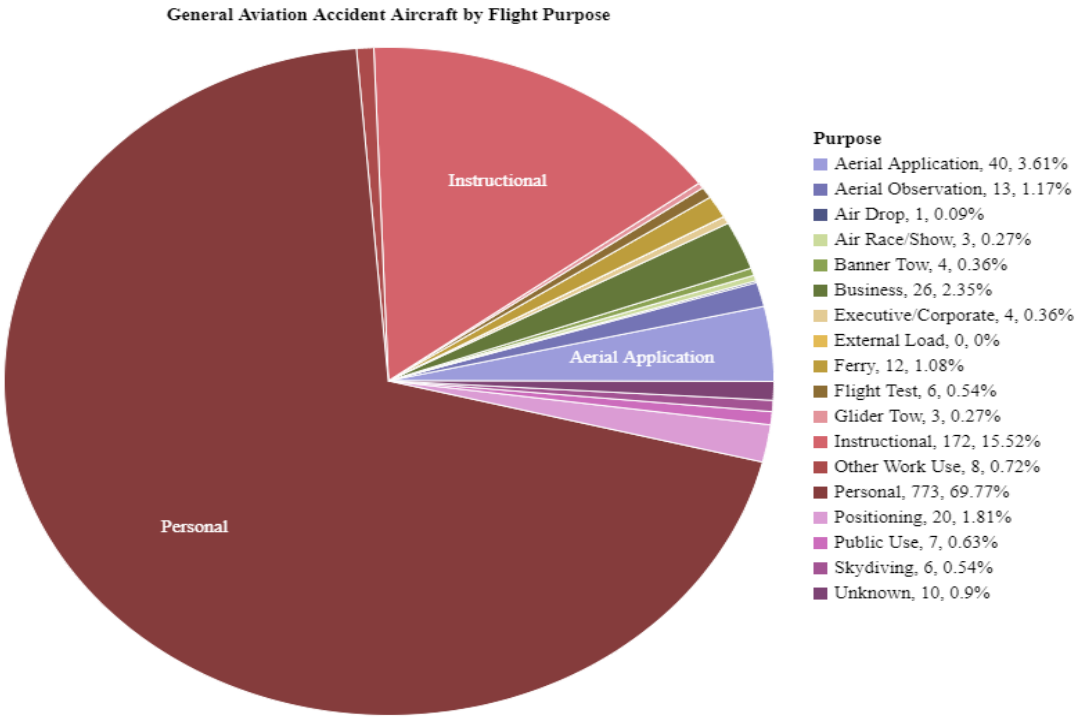


Table 1

Summary of Part 121 and GA Accidents and Fatalities from 2000 to 2019

Year	Part 121 Accidents	Part 121 Fatalities	Part 121 Flight Hrs	GA Accidents	GA Fatalities	GA Flight Hrs
2000	56	92	18,299,257	1,837	345	27,838,000
2001	46	531	17,814,191	1,728	326	25,430,000
2002	41	0	17,290,198	1,716	345	25,545,000
2003	54	22	17,467,700	1,741	352	25,997,000
2004	30	14	18,882,503	1,619	314	24,888,000
2005	40	22	19,390,029	1,671	321	23,167,712
2006	33	50	19,263,209	1,523	308	23,962,936
2007	28	1	19,637,322	1,654	288	23,818,668
2008	27	3	19,126,766	1,569	277	22,804,648
2009	30	52	17,626,832	1,481	276	20,861,866

2010	30	2	17,750,986	1,441	271	21,688,409
2011	33	0	17,962,965	1,471	270	00000000
2012	27	0	17,722,236	1,471	273	20,880,993
2013	22	9	17,779,641	1,223	221	19,492,356
2014	31	0	17,742,826	1,222	255	19,617,389
2015	28	0	17,925,780	1,211	230	20,576,072
2016	30	0	18,294,057	1,269	213	21,333,747
2017	33	0	18,581,388	1,233	203	21,702,719
2018	31	1	19,288,296	1,275	224	21,663,367
2019	40	4	19,786,547	1,220	233	21,800,689

Table 2
The Summary of five years intervals of Part 121 and GA accidents and Fatalities in Percentage and Flight Hours from 2000 to 2019.

Year	Part 121 Accidents (%)	Part 121 Fatalities (%)	Flight Hours	GA Accidents (%)	GA Fatalities (%)	Flight Hours
2000-2004	32.9	82.1	89,753,849	29.2	30.1	129,698,000
2005-2009	22.9	15.9	95,044,158	26.7	28.2	114,615,830
2010-2014	20.7	1.4	88,958,654	23.1	22.3	
2015-2019	23.5	0.6	93,876,068	21	19.4	107,076,594

Fundamentals of CRM training implementation and components of CRM training were deduced in the coding process to have been factors supporting the effectiveness of CRM training. There are six fundamentals of CRM training implementation and three components of CRM training. These fundamentals are the practices that research programs and airline operational experience suggested would benefit the program most. Table 3 shows the summary of the fundamentals and components of CRM.

Table 3
The Summary of the Fundamentals of CRM Training Implementation and Components of CRM Training

Fundamentals of CRM Training Implementation
• Assess the Status of the Organization Before Implementation • Get Commitment from All Managers, Starting with Senior Managers • Customize the Training to Reflect the Nature and Needs of the Organization • Define the Scope of the Program and an Implementation Plan • Communicate the Nature and Scope of the Program Before Startup • Institute Quality Control Procedures
Components of CRM Training
• Initial Indoctrination/Awareness • Recurrent Practice and Feedback • Continuing Reinforcement

Discussion

CRM training is designed to effectively use all resources to reduce errors, increase flight safety, and improve performance (Velazquez & Bier, 2015). According to the Federal Aviation Administration (FAA), CRM training focuses on situation awareness, communication skills, teamwork, task allocation, and decision-making within a comprehensive framework of standard operating procedures (SOP's) (FAA, 2001). In addition, the training aims to prevent accidents by improving crew performance due to better and more effective crew coordination (FAA, 2001). The evolution of the training started in 1979 but was first implemented in 1981 by United Airlines (Helmreich, Merritt, & Wilhelm, 1999). The training has evolved into the 5th generation with the introduction of the Advanced Qualification Program (AQP), which requires participating carriers to incorporate CRM models into technical training and provide CRM and Line Oriented Flight Training (LOFT) to all the flight crews (Helmreich, Merritt, & Wilhelm, 1999). CRM training is not an error-eliminating mechanism but can help improve flight safety and efficiency by mitigating human errors (Helmreich, Merritt, & Wilhelm, 1999).

The analyses of the study revealed the impact of CRM on flight safety, as the fatalities decreased drastically in commercial aviation, which is the goal of CRM training. In addition, the analyses of the accidents from 2000 to 2019 showed that 82.1% of the fatalities occurred between 2000 and 2005 and 0.6% from 2015 to 2019, which showed improvement in commercial aviation safety over the years. However, Helmreich, Merritt, & Wilhelm (2017) concluded that the effectiveness of CRM cannot be easily determined, especially through the accident rate per million flights during a finite period. Instead, the logical criteria for evaluating CRM would be the behavior of the flight crews on the flight deck and attitudes showing acceptance or rejection of CRM concepts (Helmreich, Merritt, & Wilhelm, 2017). However, further investigation of the effectiveness of CRM showed that the concept of CRM involving LOFT and recurrent training produced desired changes in the behavior of flight crews, and attitudes about flight deck management of the crews had changed positively (Helmreich, Merritt, & Wilhelm, 2017). Therefore, we can conclude that CRM training (human factors awareness) has yielded positive results in commercial aviation.

SRM is a variation of CRM with the goal of mitigating human errors by teaching pilots about human limitations and how individual performance can be maximized. It's the art of managing all the resources available to pilots before and during a flight to ensure a successful flight. The essence of the training is to enable pilots to maintain situational awareness by effectively managing automation, aircraft control, and navigation tasks. As a result, pilots accurately assess hazards, manage resulting risk potential and make sound aeronautical decisions. Furthermore, SRM training is based on proper adherence to aeronautical decision-making, risk management, controlled flight into terrain (CFIT) awareness, and situational awareness.

From the analysis of general aviation accidents, there was a slight decrease in the rate of fatalities from 2000 to 2019. However, the effectiveness or impacts of SRM cannot be linked to the slight decrease in fatalities and accident rates of general aviation operations because the data collected from NTSB also showed a decrease in flight hours per million flights from 2000 to 2019. Most general aviation incidents and accidents analyzed are mainly caused by human factors that should have been addressed if SRM is effective. Hence, SRM has not yielded positive results compared to CRM.

A further assessment of the CRM training advisory circular revealed that the fundamentals of CRM training implementation and components of CRM training might have contributed to its effectiveness. Nevertheless, these fundamentals and components are missing in the implementation of SRM. For example, one of the fundamentals of CRM states CRM training is customized to reflect the nature and needs of the organization. Still, SRM is general in scope, not customized to reflect and meet the needs of specific operations in general aviation. General aviation operations consist of personal, instructional, aerial observation, ferry, and many other types of flying. Customizing the training to meet the need of specific operations may yield positive results in terms of reducing general aviation accidents and incidents. For instance, as shown by our analyses, personal flying and instructional flying have the highest number of accidents and fatality rates in general aviation, of which personal flying accounts for 67.77% and instructional flying accounts for 15.52% of general aviation fatalities in 2018.

The quality control procedures of the fundamentals of CRM training implementation are an art of monitoring the delivery of training and determining areas where training can be strengthened. In addition, the instructors, also known as the facilitators, collect systematic feedback from participants in the training through surveys. This is very important in determining the effectiveness of training programs. Nevertheless, such procedures are missing regarding SRM because there's no standard way of monitoring and determining general aviation pilots' compliance with the principles of SRM, especially when they graduate from flight schools.

Two important CRM training components are recurrent practice, and Feedback, and continuing reinforcement. These concepts are adopted to ensure pilots practice newly improved CRM skills and to receive feedback on their effectiveness. This is because one-time exposures to the concept of CRM are simply insufficient to produce desired results. So, CRM training is a recurrent training program in commercial aviation. On the contrary, there's no standard way of knowing if general aviation pilots review and comply with the principles of SRM on a regular

basis. In addition, pilots are humans and are subject to many limitations, such as forgetting lessons learned, but things most recently learned are best remembered (FAA, 2016).

Conclusions

CRM plays a crucial role in mitigating human errors and enhancing flight safety in commercial aviation by fostering effective communication, teamwork, and decision-making among flight crew members. Its design enables a culture where every member of the crew feels empowered to speak up, share concerns, and contribute to safe operations. More importantly, CRM training equips pilots and crew members with the skills to manage challenging situations, such as emergencies or unexpected events, with efficiency and coordination, ultimately enhancing overall flight safety in commercial aviation. Analysis of the data of commercial aviation accidents from 2000 to 2019 revealed that CRM training had produced desired outcomes, mitigated human error, and improved safety. In addition, the analyses confirmed that the accident rates from 2000 to 2019 decreased from 82.1% between 2000 to 2000 to 0.6% between 2015 to 2019, which confirmed that CRM training is producing the desired results.

The fundamentals of CRM training implementation and components of CRM training have contributed to CRM's effectiveness in mitigating human errors, thereby positively impacting flight safety. In addition, the customization of CRM training to reflect the nature and specific needs of the organization, recurrent practice, and feedback, and continuing reinforcement are major contributing factors to the effectiveness of CRM training. If introduced into the SRM model, general aviation safety records will likely improve.

From the analyses of general aviation accidents, there was a slight decrease in aviation accidents from 2000 to 2019. However, this metric cannot be used to justify the effectiveness of SRM because the number of flight hours per million flights decreased from 2000 to 2019. Therefore, the implementation of SRM has not been effective compared to CRM in mitigating human errors and enhancing flight safety. Further investigation revealed that a lack of consistent and monitored human factors awareness training in GA might have contributed to the reason SRM is not as effective as CRM. Most GA pilots lack personal development to ensure continuous human factors training. Therefore, consistent and monitored human factors awareness training in GA will reinforce SRM skills in GA pilots on a regular basis.

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