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Causes and risk factors for fatal accidents in non-commercial twin engine piston general aviation aircraft

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ABSTRACT

Accidents in twin-engine aircraft carry a higher risk of fatality compared with single engine aircraft and constitute 9% of all general aviation accidents. The different flight profile (higher airspeed, service ceiling, increased fuel load, and aircraft yaw in engine failure) may make comparable studies on single-engine aircraft accident causes less relevant. The objective of this study was to identify the accident causes for non-commercial operations in twin engine aircraft.

A NTSB accident database query for accidents in twin piston engine airplanes of 4–8 seat capacity with a maximum certified weight of 3000–8000 lbs. operating under 14CFR Part 91 for the period spanning 2002 and 2012 returned 376 accidents. Accident causes and contributing factors were as per the NTSB final report categories. Total annual flight hour data for the twin engine piston aircraft fleet were obtained from the FAA. Statistical analyses employed Chi Square, Fisher's Exact and logistic regression analysis.

Neither the combined fatal/non-fatal accident nor the fatal accident rate declined over the period spanning 2002–2012. Under visual weather conditions, the largest number, $n = 27$, (27%) of fatal accidents was attributed to malfunction with a failure to follow single engine procedures representing the most common contributing factor. In degraded visibility, poor instrument approach procedures resulted in the greatest proportion of fatal crashes. Encountering thunderstorms was the most lethal of all accident causes with all occupants sustaining fatal injuries. At night, a failure to maintain obstacle/terrain clearance was the most common accident cause leading to 36% of fatal crashes. The results of logistic regression showed that operations at night (OR 3.7), off airport landings (OR 14.8) and post-impact fire (OR 7.2) all carried an excess risk of a fatal flight.

This study indicates training areas that should receive increased emphasis for twin-engine training/recency. First, increased training should be provided on single engine procedures in the event of an engine failure. Second, more focus should be placed on instrument approaches and recovery from unusual aircraft attitude where visibility is degraded. Third, pilots should be made aware of appropriate speed selection for inadvertent flights in convective weather. Finally, emphasizing the importance of conducting night operations under instrument flight rules with its altitude restrictions should lead to a diminished proportion of accidents attributed to failure to maintain obstacle/terrain clearance.

1. Introduction

General aviation (14CFR Part 91) includes all civilian aviation with the exception of operations involving paid passenger transport the latter covered under 14CFR Part 121 and 135. 14CFR Part 91 refers to a set of FAA regulations that govern the operation of small, non-commercial aircraft within the United States (http://www.ecfr.gov/cgi-bin/text-idx?node=14:2.0.1.3.10) whereas 14CFR Part 121 and 135 are the comparable but more stringent rules applying to airlines and air-taxi operations respectively. Although accidents for the airlines have dramatically declined over the last decade (Li and Baker, 2007), such a decrease has not been witnessed in general aviation. In fact, general aviation accounts for the overwhelming majority (94%) of civil aviation fatalities in the United States (Kenny, 2012; Li and Baker, 2007) and represents one of the last unresolved safety challenges for aviation. Furthermore general aviation accidents carry an associated annual cost of $1.6–4.6 billion to individuals and institutions affected (e.g. family and non-family incurring injury and/or loss of life, insurance companies, accident investigation costs) when taking into account

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hospital costs, loss of pay with a fatal accident and loss of the aircraft (Sobieralski, 2013). In all likelihood these costs would be even higher were litigation costs assessed as well.

Approximately 7% of the general aviation fleet is comprised of multi-engine piston aircraft. Moreover, of all general aviation accidents 9% occur in twin-engine, piston-powered aircraft (Kenny, 2012). General aviation accidents in these aircraft carry a higher risk of fatality compared with single engine aircraft (Kenny, 2012). Although the reason for the higher fatality rate is unknown several factors may contribute. First, these aircraft typically have a higher airspeed, service ceiling and carry an increased fuel load (and therefore increased potential for a post-impact fire). Second, unlike a single engine aircraft, an engine failure in a twin-engine airplane (with the exception of aircraft with centerline thrust twin engines) creates a yawing tendency due to the asymmetrical thrust a characteristic which may enhance the chance of an aerodynamic stall. Conversely, multi-engine aviators are likely to have more aviation experience than pilots flying single engine aircraft. These differences may make prior studies on single-engine aircraft accident causes less relevant.

Although there are several published studies on general aviation fatal crashes (Bazargan and Guzhva, 2007; Dambier and Hinkelbein, 2006; Grabowski et al., 2002; Li and Baker, 2007), to the knowledge of the author, none have specifically focused on the causes and temporal changes for twin-engine piston aircraft operating under the 14CFR Part 91 umbrella. With few exceptions (Shao et al., 2014a,b), research on aviation accidents typically aggregate single and multiple engine-powered aircraft (Groff and Price, 2006; Li and Baker, 1999; Nakamura et al., 1997; Wiegmann and Taneja, 2003). In addition, there is also the tendency of studies to cite general (e.g. pilot error, pilot-related) (Dambier and Hinkelbein, 2006; Li et al., 2001; Shkrum et al., 1996) rather than specific causes. Where specific accident causes are provided, studies often fail to distinguish between single and multi-engine aircraft. The Joseph T. Nall report (hereafter referred to as the Nall report) compiled by *The Air Safety Institute* (http://www.aopa.org/Pilot-Resources/Safety-and-Technique/Accident-Analysis/Joseph-T-Nall-Report) is a biennial report on general aviation accidents. While extremely comprehensive, the Nall report documents several accident causes (e.g. fuel mismanagement, aerodynamic stalls, failure to maintain obstacle/terrain clearance, thunderstorms, instrument approach deficiencies, failure to maintain control and spatial disorientation) across the entire general aviation fixed-wing fleet with little distinction between single and multi-engine aircraft. Additionally, this report fails to identify risk factors that may also contribute to fatal crashes. The objective of the current study was to determine the causes of fatal and non-fatal accidents in twin-piston engine powered airplanes operating under 14CFR Part 91 as well as to identify risk factors for fatal crashes for the period spanning 2002–2012.

2. Methods

The NTSB (2014 Aug release) Access database was downloaded (http://www.ntsb.gov/avdata/Access/) and queried for accidents occurring for the period spanning 2002 and 2012 in twin piston engine aircraft (airplane category) of 4–8 seat capacity with a maximum certified weight of 3000–8000 lbs. To be included in the current study aircraft operating under 14CFR Part 91 also fulfilled the following criteria: (a) engine horsepower of 150–499 engine) (b) exclusion of homebuilt aircraft (c) flights restricted to the purpose of business or personal use. Data were exported to Excel and, where applicable, de-duplicated in that program. This strategy returned 376 accidents comprised of 150 and 226 fatal and non-fatal accidents respectively. A fatal accident was defined as any in which one, or more, occupants perished within 30 days of the accident (Code of Federal Regulations-49CFR830.2).

Visual conditions were operationally defined as a vertical visibility (above the airport) equal to, or greater than, 3000 feet and a horizontal visibility of 3 statute miles or more. Conversely, instrument flight conditions (also referred to herein as degraded or reduced visibility) constituted weather where the vertical visibility value was less than 3000 feet or horizontal visibility was lower than 3 statute miles. Lethality of accidents was defined as the percentage of occupants sustaining fatal injuries.

Accident causes and contributing factors categories used a classification scheme identical to the NTSB final report. Abbreviations were as follows: Convective WX, thunderstorms; FMC/SD, failure to maintain control/spatial disorientation; FMOTC, failure to maintain obstacle/terrain clearance; Fuel, fuel exhaustion/contamination/mismanagement; landing/takeoff- errors in the landing/takeoff phase. The planned accident flight distance was computed point to point using the AOPA FlyQ Web tool (http://www.aopa.org/flightplanning/flyqweb/index.cfm). Denominator data (total annual flight hour data for the twin engine piston aircraft fleet designated for personal/business purpose) for determining accident rate was obtained from the FAA (http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/). The methodology used for collection of data for the FAA survey has been described in a previous study.[1]

2.1. Statistics

All statistical analyses were performed using the SPSS (version 22) software package. Chi Square and Fishers Exact (the latter test used when expected frequencies were ≤ 5 (Field, 2009)) methods were employed to determine if a difference in fatal accident proportions comparing the initial time period and a subsequent period was statistically significant. For a test of trend for fatal accident proportions across all time periods, a Chi-Square linear-by-linear association output was used for trend assessment (Agresti, 2012). Chi square analysis was also employed to determine if the percentage of the various accident causes under visual and instrument weather conditions were statistically significantly different.

Logistic regression was used to identify risk factors for fatal accidents using 95% confidence intervals. However, the analysis was hindered by the problem of missing data for several parameters. For this reason and since independent variables are often associated with each other, a two-step approach as advocated prior (Hosmer et al., 2013) was performed. First, a uni-variable analysis was undertaken on parameters related to airman demographics (Bazargan and Guzhva, 2011; Li and Baker, 1999), flight experience (Li and Baker, 1999; Li et al., 2005) and certification (Groff and Price, 2006), aircraft characteristics (Freitas, 2014), weather and lighting conditions (Bazargan and Guzhva, 2007; Groff and Price, 2006; Li and Baker, 1999) and accident flight distance (Groff and Price, 2006). Second, a multi-variable analysis was performed to statistically adjust the estimated effect of each variable in the model for differences in the distributions of and association among the other independent variables (Hosmer et al., 2013). Risk factors identified from the bi-variable analysis and showing a Wald significance (which assesses the contribution of each predictor (Field, 2009)) of $p < 0.05$ were advanced into the multi-variable model building. Here a "block entry" method was used where each covariable was added sequentially. If the change in the Chi square value between models

[1] Methodology for the 2010 General Aviation and Part 135 Activity Survey. 2010. Federal Aviation Administration.