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Statistical Analyses for General Aviation Accidents

February 2013

Final Report

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16. Abstract

The research team at Embry-Riddle Aeronautical University conducted a statistical analysis of the factors contributing to fatal general aviation (GA) accidents. The analyzed factors included flight rules, light conditions, weather condition, flight phases, pilot characteristics, and aircraft complexity. The study focused on identifying associations and patterns between contributing flight elements and risk factors.

The binary logistic regression analysis was conducted on a large sample of GA accident data from 1982 to 2009 for the nine Federal Aviation Administration regions. The goal of binary logistic regression analysis was to predict values of a categorical-dependent variable. The dependent value in this study was the probability of an accident falling into a fatal category. This analysis statistically identified the factors that increased the likelihood of a GA accident in each region becoming fatal. The Statistical Package for the Social Sciences was used for this statistical analysis.

The factors that were statistically significant for increasing the probability that a GA flight would be involved in a fatal accident were identified for each region.

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LIST OF ACRONYMS

ASIAS	Aviation Safety Information Analysis and Sharing
CRM	Crew Resource Management
FAA	Federal Aviation Administration
GA	General aviation
IFR	Instrument flight rule
IMC	Instrument meteorological conditions
NTSB	National Transportation Safety Board
SPSS	Statistical Package for the Social Sciences
VFR	Visual flight rule

EXECUTIVE SUMMARY

The research team at Embry-Riddle Aeronautical University conducted a statistical analysis of the factors contributing to general aviation (GA) fatal accidents. The analyzed factors included flight rules, light conditions, weather condition, flight phases, pilot characteristics, and aircraft complexity. The study focused on identifying associations and patterns between contributing flight elements and risk factors.

The binary logistic regression analysis was conducted on a large sample of GA accident data from 1982 to 2009 for the nine Federal Aviation Administration regions. The goal of binary logistic regression analysis was to predict values of a categorical-dependent variable. The dependent value in this study was the probability of an accident falling into a fatal category. This analysis statistically identified the factors that increased the likelihood of a GA accident in each region to become fatal. The Statistical Package for the Social Sciences was used for this statistical analysis.

The factors that were found statistically significant for increasing the probability that a GA flight would be involved in a fatal accident for each region were:

- Western Pacific—flying at night; flying in instrument meteorological conditions (IMC); flying with a second pilot onboard; flight time of pilots of less than 5 hours over the preceding 30 days; takeoff, approach/landing, and maneuvering phase of flight.

- Southwest—flying at night; flying in IMC; pilot flying without wearing a seat belt; pilot flying without wearing a shoulder harness; takeoff, approach/landing phase of flight.

- Alaskan—flying in IMC; takeoff, approach/landing phase of flight.

- Central—flight filed with instrument flight rules (IFR); flying at night; descent, approach/landing, and maneuvering phase of flight.

- Great Lakes—flying in IMC; flying with a second pilot onboard; pilot flying without wearing a seat belt; gender of the pilot; taxi, takeoff, approach/landing, and maneuvering phase of flight.

- Northwest Mountain—flight filed with IFR/visual flight rules; approach/landing phase of flight.

- New England—flying in IMC; performing a cross-country flight; type-rated pilots; flight time of pilots of less than 5 hours over the preceding 30 days; taxi, takeoff, approach/landing, and maneuvering phase of flight.

- Southern—flight filed with IFR; flying at night; flying in IMC; flying in multiengine aircraft; type-rated pilots; pilot flying without wearing a seat belt; pilot flying without wearing a shoulder harness; takeoff, descent, approach/landing, and maneuvering phase of flight.

- Eastern—flying at night; flying in IMC; approach/landing, and maneuvering phase of flight.

1. INTRODUCTION.

1.1 BACKGROUND.

According to the National Transportation Safety Board (NTSB), general aviation (GA) is accountable for 82% of total air transport-related accidents and incidents and 83% of all air transport-related fatalities. By applying statistical analysis and logistic regression to a large sample of GA accidents from 1982 to 2009, factors that increase the chance of a fatal GA accident for each region of the United States were identified. Many variables involved in GA accidents were analyzed in this study, including light condition, flight phase, wind condition, aircraft characteristics, and aircraft complexity. While many factors that contribute to fatal accidents were in line with expectations, some of them were counterintuitive.

1.2 SCOPE OF REPORT.

The research team at Embry-Riddle Aeronautical University conducted statistical analyses of the factors contributing to fatal GA accidents. This report is an extension of two publications resulting from those analyses [1 and 2]. Additionally, those analyses were conducted on a national basis; however, the analyses discussed in this report are regionally organized to investigate multiple flight-related factors contributing to fatalities in GA accidents. The study focused on identifying associations and patterns between contributing flight elements and risk factors.

1.3 THE NTSB DATABASE.

The federal regulations require a pilot or operator of an aircraft to immediately notify the NTSB regional office nearest to the accident. An accident is defined as an occurrence associated with the operation that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death, or serious injury, or in which the aircraft receives substantial damage.

The NTSB uses a factual report (NTSB form 6120 [3]) that contains more than 400 fields for data pertaining to a GA accident. These reports are maintained in a publicly accessible database containing more than 60,000 aviation accidents and incidents, describing all information relevant to the accident or incident.

The aircraft accident database from the Aviation Safety Information Analysis and Sharing (ASIAS) system was provided by the Federal Aviation Administration (FAA) in the form of a Microsoft® Access® file. In August 2010, the research team obtained an updated database. The database used for the previous report [4] had 65,698 unique events, whereas the updated database provided 66,633 unique events from 1982-2009 for this report. All accident data used in this report were extracted from the ASIAS system for flights under Title 14 Code of Federal Regulations Part 91 [5]. Out of more than 400 data fields, only the quantifiable data that was not redundant were selected. In particular, 25 variables related to pilot and airplane characteristics, procedural attributes, flight conditions, phases of flight, and time periods were included in the analysis. Table 1 shows the 25 selected variables with their coding and descriptions.

Table 1. Variables Included in the Logistic Regression Analysis

Variable	Description	Coding
FATAL	Indicates a fatal accident	1 - accident is fatal, 0 - otherwise
FPF	Indicates whether a VFR, IFR, or VFR/IFR flight plan were filed	1 -flight plan was filed, 0 - otherwise
LCOND	Indicates light conditions at the time of accident	0 - day; 1 - dawn; 2 - dusk; 3 - night
IMC	Indicates whether an accident took place in IMC	1 – IMC, 0 – otherwise
XCNT	Indicates whether an accident occurred farther than 50 nautical miles from the origin airport (cross-country flight)	1 - cross country flight, 0 - otherwise
WIND	Indicates wind velocity in the area at the time of the accident	Wind speed in knots
MENG	Indicates whether an accident airplane had more than one engine	1 - multiengine, 0 - otherwise
TYPR	Indicates whether a pilot was type rated at an accident airplane	1 - type rated, 0 - otherwise
SIC	Indicates whether a second pilot was onboard the aircraft at the time of the accident. Second pilot is defined as any certified or formerly certified pilot who could have operated or interfered with the control	1 - second pilot onboard, 0 - otherwise
SBLT	Indicates whether the pilot was wearing a seat belt at the time of the accident	1 - pilot was wearing a seat belt 2 - otherwise
SHARN	Indicates whether the pilot was wearing a shoulder harness at the time of the accident	1 - pilot was wearing a shoulder harness, 0 - otherwise
MED	Indicates type of medical certificate held by the pilot at the time of the accident	1 - class 1 medical; 2 - class 2 medical, 3 - class 3 medical
GENDER	Indicates the gender of the pilot	1 - female, 0 - male
AGE	Indicates the age of the pilot	Age in years
TTIME	Indicates total flight experience of the pilot	Number of hours of total flight time
TFT	Indicates whether the total flight experience of the pilot is between 50 and 300 hours	1 - pilot had 50-300 hours, 0 - otherwise
LMF	Indicates whether the pilot had less than 5 hours of flight time over the last 30 days	1 - less than 5 hours, 0 - otherwise
LMH	Indicates whether the pilot had more than 100 hours of flight time over the last 30 days	1 - more than 100 hours, 0 - otherwise
TAXI	Indicates whether the airplane was taxiing at the time of the accident	1 - taxiing, 0 - otherwise
TAKEOFF	Indicates whether the accident happened during takeoff	1 - takeoff, 0 - otherwise
CLIMB	Indicates whether the accident happened during climb	1 - climb, 0 - otherwise
DESCENT	Indicates whether the accident happened during descent	1 - descent, 0 - otherwise
APPLDG	Indicates whether the accident happened during approach or landing	1 - approach or landing, 0 - otherwise
MANV	Indicates whether the accident happened during maneuvering	1 - maneuvering, 0 - otherwise
YEAR	Indicates the period when the accident occurred	1 - 1982, 2 - 1983, 3 - 1984, 4 - 1985, 5 - 1986, 6 - 1987, 7 - 1988, 8 - 1989, 9 - 1990, 10 - 1991, 11 - 1992, 12 - 1993, 13 - 1994, 14 - 1995, 15 - 1996, 16 - 1997, 17 - 1998, 18 - 1999, 19 - 2000, 20 - 2001, 21 - 2002, 22 - 2003, 23 - 2004, 24 - 2005, 25 - 2006, 26 - 2007, 27 - 2008, 28 - 2009,

VFR = Visual flight rules
IFR = Instrument flight rules
IMC = Instrument meteorological conditions
*All variables in table 1 are defined in appendix A.

2. STATISTICAL ANALYSIS.

The goal of this study was to find associations and patterns among fatal accidents by examining all GA accidents. Multiple factors that increase the likelihood of a GA accident in the U.S. becoming fatal were statistically identified by applying binary logistic regression analysis on a large sample of GA accident data from 1982 to 2009 for each region.

Before performing the analysis, the sample was meticulously screened to examine the missing variables, outliers, and the adequacy with respect to the assumption of normality. The data screening resulted in the identification and removal of several outliers' entries. Careful examination of missing variables did not discover any patterns, suggesting that missing variables were randomly distributed in the sample.

The goal of binary logistic regression analysis is to predict values of a categorical dependent variable—essentially attempting to predict membership into one of two groups. In this study, the dependent value was the probability of an accident falling into a fatal category or an accident caused by pilot error. Logistic regression is robust to violations of the normality assumption and does not require the predictor variables to have equal variances within each group. Similar studies [1 and 2] were conducted on a national level, and logistic regression was the best methodology in those studies.

The Statistical Package for the Social Sciences (SPSS) [6] was used to conduct the logistic regression for all statistical analyses. SPSS provided the following information/parameters:

- Goodness of fit—This metric identified whether the applied logistic regression model was applicable to the data for the region. As an example, table 2 provides the goodness of fit on data sample and shows that the model is statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 450). The model correctly classified 86.5% of the cases.

- Coefficient—In the logistic regression, a statistical test was used to determine if the logistic coefficient was different from 0. A coefficient of 0 indicated the variable had no impact on the dependent variable. Values other than 0 showed the impact on the dependent variable. A positive value of coefficient for variable indicated that the variable was positively related to the dependent variable, and a negative value indicated that the variable was negatively relative to the dependent variable. As an example, table 2 shows the results of binary logistic regression to sample data. As the table implies, LCOND (light conditions, as defined in table 1) has a positive coefficient and IMC (instrument meteorological conditions) has a negative coefficient indicating they are positively and negatively related to fatal accidents (dependent variable), respectively.

- Significance—This refers to the level of statistical significance. Small values (less than 0.05) indicated that the coefficient was statistically significant. In this report, two levels of significance were used: (1) significance level of 5%, which included significance values between 0.05 and 0.01 (represented by * in the coefficient value); and (2) the significance level of 1%, which included the significance values that were below 0.01

(represented by ** in the coefficient values). As shown in table 2, the significance value of LCOND was less than 0.05, but more than 0.01 (indicated by * in the coefficient value) indicating LCOND was a significant contribution factor in a GA fatal accident (dependent variable). Similarly, the value of the significance parameter for IMC is below 0.01 (indicated by ** in the coefficient value), indicating IMC had a significant contribution in determining a GA accident to be fatal (more significant than LCOND). Statistically, the significance level above 0.05 had no significant contribution to the dependent variable. The GENDER variable had a significance parameter value above 0.05 (coefficient represented without *), indicating it was not a significant contribution factor in a GA fatal accident.

- Odds ratio—This refers to the value by which the odds of the event change when the independent variable moves to a higher group. If the value is greater than 1, the odds are increased; if the value is less than 1, the odds are decreased. A value of 1 leaves the odds unchanged. As shown in table 2, the odds ratio for LCOND has a value greater than 1, which indicates that any increase in LCOND variable will significantly increase the odds 1.227 times (see Hair et al. [7], for further technical explanation of these parameters). As explained in table 1, larger LCOND values imply darker conditions.

Table 2. Logistic Regression Parameter Estimates and Odds Ratios

Variable	Coefficient	Significance	Changes in Odds
LCOND	0.2048*	0.027	1.227
IMC	-1.790**	0.000	0.167
GENDER	-0.41	0.467	0.663
Chi-square of the model = 450		Overall correctly classified cases = 86.5%	

For all nine regions (detailed in section 3), this report statistically identifies multiple factors, as shown in table 1, that increase the likelihood that a GA accident in U.S. will become fatal. This statistical analysis was done by applying logistic regression analysis on a large sample of GA accident data from 1982 to 2009. The mathematical model of actual logistic regression for this research is explained in appendix A.

3. REGIONS.

The GA accident data were analyzed for all nine FAA regions throughout the U.S., which are defined as follows:

- Region 1—Western Pacific Region consists of Arizona, California, Hawaii, and Nevada

- Region 2—Southwest Region consists of Arkansas, Louisiana, New Mexico, Oklahoma, and Texas

- Region 3—Alaskan Region covers the state of Alaska

- Region 4—Central Region consists of Iowa, Kansas, Missouri, and Nebraska

- Region 5—Great Lakes Region consists of Illinois, Indiana, Michigan, Minnesota, North Dakota, Ohio, South Dakota, and Wisconsin

- Region 6—New England Region consists of Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont

- Region 7—Northwest Mountain Region consists of Colorado, Idaho, Montana, Oregon, Utah, Washington, and Wyoming

- Region 8—Southern Region consists of Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, Puerto Rico, South Carolina, and Tennessee

- Region 9—Eastern Region consists of Delaware, Maryland, New Jersey, New York, Pennsylvania, Virginia, West Virginia, and Washington D.C.

3.1 REGION 1—WESTERN PACIFIC.

This section discusses variables analyzed for the Western Pacific Region. Due to a large number of missing data in MENG (multiengine aircraft), this variable was eliminated from the study for the Western Pacific Region. According to the logistic regression results, as shown in table 3, the combination of LCOND, IMC, SIC, LMF, TAKEOFF, APPLDG, MANV, and YEAR variables, as defined below, were found to be highly statistically significant coefficients in the Western Pacific Region. As shown in table 3, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 564). The model correctly classified 88.5% of the cases.

- Lighting Condition (LCOND)—As expected, the coefficient of lighting conditions (LCOND) was positive and significant, indicating that a darker environment was associated with increased probability of an accident to be fatal. The odds ratio of 1.2508 for the lighting condition variable suggested that, although a one-step change in the lighting condition (e.g., from dawn to night) resulted in a small change in probability, the change from daylight to night (three-step change) resulted in a substantial increase in the likelihood of a fatal accident.

- Instrument Meteorological Condition (IMC)—IMC means the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 1.861 for IMC suggested that a low- or bad-visibility environment increased the probability of a fatal accident. In addition, the odds ratio of 6.398 for IMC was the highest for all the variables, indicating that IMC was a major contributor in fatal GA accidents in the Western Pacific Region.

- Second Pilot Onboard (SIC)—Another counterintuitive result was the positive and significant coefficient of SIC, which indicated whether a second pilot was onboard the airplane at the time of the accident. More than 20 percent of the GA airplanes involved

in an accident in the sample had a copilot onboard, and apparently that significantly increased the probability of being involved in a fatal accident. Conventional wisdom suggests that a copilot onboard would help the pilot in command in the case of an unexpected emergency. However, for this help to be constructive, GA airplane pilots should understand how to properly use available in-flight human resources. Without such an understanding, a copilot onboard the GA airplane during an emergency situation would only make the situation worse, possibly interfering with the flight controls or influencing the ability of the pilot in command to resolve the situation. Although U.S. airlines have implemented Crew Resource Management (CRM) training with an emphasis on principles and concepts that improve crew performance and flight safety, a typical GA airplane pilot has never taken a CRM course. The results from this study imply that such a course would decrease the number of fatal GA accidents.

- Pilot's Flight Time Over the Last 30 Days (LMF)—The LMF dummy variable indicates that the pilot flew less than 5 hours in the 30 days preceding the accident. This variable was included in the analysis to examine if less-practiced pilots (with less than 5 hours in 30 days) have a higher probability of a fatal accident. Positive and significant coefficient of 0.442 for LMF variable indicated that less-practiced pilots are more likely to be involved in a fatal accident than pilots with more normal (5 to 100 hours) flight schedules in the preceding 30 days.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributed to fatal accidents. Out of the six, three variables were found to be significant: TAKEOFF, APPLDG, and MANV.

  Negative and significant coefficients of TAKEOFF and APPLDG (approach or landing) imply that airplanes in takeoff or approach/landing phases of flight are less likely to be involved in fatal accidents.

  MANV has the positive and significant coefficient of 1.407, which implies that an airplane in the maneuvering stage of flight is more likely to be involved in a fatal accident. Also MANV has the second highest changes in odds ratio (IMC being the first) indicating that MANV is a significant contributor in fatal GA accidents in the Western Pacific Region.

- Year of Accidents (YEAR)—The YEAR variable was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested there was a downward trend in GA accidents—over the 28-year sample period, the probability of an accident becoming fatal significantly decreased.

Table 3. Logistic Regression Parameter Estimates and Odds Ratios for the Western Pacific Region

Variable	Coefficient	Significance	Changes in Odds
FPF	0.284	0.105	1.328
LCOND	0.224**	0.001	1.251
IMC	1.856**	0.000	6.398
XCNT	0.007	0.965	1.007
LogWIND	-0.022	0.889	0.979
TYPR	-0.073	0.692	0.930
SIC	0.555**	0.001	1.743
SBLT	-0.436	0.501	0.646
SHARN	-0.164	0.260	0.849
MED	0.004	0.973	1.004
GENDER	-0.396	0.259	0.673
LogAGE	0.677	0.281	1.968
LogTTIME	-0.078	0.632	0.925
TFT	0.182	0.346	1.199
LMF	0.442**	0.009	1.556
LMH	0.115	0.824	1.122
TAXI	-20.003	0.996	0.000
TAKEOFF	-0.954**	0.000	0.385
CLIMB	0.340	0.266	1.405
DESCENT	0.599	0.545	1.820
APPLDG	-2.16**	0.000	0.115
MANV	1.048**	0.000	2.853
YEAR	-0.059**	0.000	0.943
Chi-square of the model = 564		Overall correctly classified cases = 88.5%	

3.2 REGION 2—SOUTHWEST.

This section discusses the variables analyzed for the Southwest Region. According to the logistic regression results, the combination of LCOND, IMC, SBLT, TAKEOFF, APPLDG, and YEAR variables, as defined below, was found to be highly statistically significant coefficients in the Southwest Region. As shown in table 4, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 448). The model correctly classified 86.8% of the cases.

- Lighting Condition (LCOND)—As expected, the coefficient of 0.252 for lighting conditions (LCOND) was positive and significant, indicating that a darker environment was associated with the increased probability of an accident to be fatal. The odds ratio of 1.286 for the lighting condition variable suggested that, although a one-step change in the

lighting condition (e.g., from dawn to night), resulted in a small change in probability, the change from daylight to night (a three-step change) resulted in a substantial increase in the likelihood of a fatal accident.

- Instrument Meteorological Condition (IMC)—IMC means the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 2.007 for IMC suggested that a low- or bad-visibility environment increased the probability of a fatal accident. In addition, the odds ratio of 7.444 for IMC was the highest for all the variables, indicating that IMC was a major contributor in fatal GA accidents in the Southwest Region.

- Seat Belts (SBLT)—SBLT indicates whether the pilot was wearing a seat belt at the time of the accident. As suggested by the negative and highly statistically significant coefficient of -2.807 for SBLT and a very low odds ratio of 0.060, wearing a seat belt considerably reduced the probability of an accident to be fatal.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributed to fatal accidents. Out of the six, two variables were found to be significant contributors in fatal GA accidents: TAKEOFF and APPLDG.

  Negative and significant coefficients of TAKEOFF and APPLDG (approach or landing) imply that airplanes in takeoff or approach/landing phases of flight are less likely to be involved in a fatal accident.

- Year of Accidents (YEAR)—The YEAR variable was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested there was a downward trend in GA accidents—over the 28-year sample period the probability of an accident becoming fatal significantly decreased.

Table 4. Logistic Regression Parameter Estimates and Odds Ratios for the Southwest Region

Variable	Coefficient	Significance	Changes in Odds
FPF	0.121	0.647	1.129
LCOND	0.252**	0.007	1.286
IMC	2.007**	0.000	7.444
XCNT	0.080	0.727	1.084
LogWIND	0.303	0.239	1.354
MENG	0.407	0.235	1.503
TYPR	0.450	0.073	1.569
SIC	0.323	0.248	1.381
SBLT	-2.807*	0.037	0.060
SHARN	0.414	0.050	1.513
MED	0.033	0.862	1.033

Table 4. Logistic Regression Parameter Estimates and Odds Ratios for the Southwest Region (continued)

Variable	Coefficient	Significance	Changes in Odds
GENDER	-0.495	0.380	0.610
LogAGE	1.360	0.127	3.896
LogTTIME	-0.047	0.829	0.954
TFT	-0.037	0.890	0.963
LMF	0.101	0.689	1.106
LMH	-0.437	0.526	0.646
TAXI	-21.172	0.998	0.000
TAKEOFF	-0.775*	0.014	0.461
CLIMB	-1.665	0.113	0.189
DESCENT	-0.401	0.724	0.670
APPLDG	-1.903**	0.000	0.149
MANV	0.439	0.167	1.551
YEAR	-0.136**	0.000	0.873
Chi-square of the model = 448			Overall correctly classified cases = 86.8%

3.3 REGION 3—ALASKAN.

This section discusses the variables analyzed for the Alaskan Region. According to the logistic regression results, as shown in table 5, the combination of IMC, TAKEOFF, and APPLDG variables, as defined below, was found to be highly statistically significant coefficients in the Alaskan Region. As shown in table 5, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 64). The model correctly classified 96% of the cases.

- Instrument Meteorological Condition (IMC)—IMC means the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 2.333 for IMC suggested that a low- or bad-visibility environment increased the probability of a fatal accident. Also the odds ratio of 10.313 for IMC was the highest for all the variables, indicating that IMC was a major contributor in fatal GA accidents in the Alaskan Region.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributed to fatal accidents. Out of the six, two variables were found to be significant: TAKEOFF and APPLDG.

  Negative and highly significant coefficients of TAKEOFF and APPLDG (approach or landing) imply that airplanes in takeoff or approach/landing phases of flight are less likely to be involved in fatal accidents. A significance level of 5% implies that the TAKEOFF and APPLDG are highly statistically significant.

Table 5. Logistic Regression Parameter Estimates and Odds Ratios for the Alaskan Region

Variable	Coefficient	Significance	Changes in Odds
FPF	0.201	0.628	1.223
LCOND	0.266	0.206	1.305
IMC	2.333**	0.000	10.313
XCNT	-0.359	0.347	0.698
LogWIND	0.179	0.654	1.195
MENG	-0.745	0.531	0.475
TYPR	0.158	0.855	1.171
SIC	-0.362	0.669	0.696
SBLT	-25.146	0.999	0.000
SHARN	0.398	0.348	1.488
MED	-0.170	0.620	0.844
GENDER	0.741	0.504	2.099
LogAGE	0.807	0.669	2.241
LogTTIME	0.111	0.796	1.117
TFT	-0.208	0.760	0.812
LMF	-0.613	0.431	0.542
LMH	-0.394	0.738	0.674
TAXI	-19.290	0.998	0.000
TAKEOFF	-1.711*	0.010	0.181
CLIMB	-0.416	0.699	0.660
DESCENT	-18.656	0.999	0.000
APPLDG	-0.95*	0.020	0.387
MANV	-1.327	0.091	0.265
YEAR	-0.041	0.277	0.960
Chi-square of the model = 64		Overall correctly classified cases = 96%	

3.4 REGION 4—CENTRAL.

This section discusses the variables analyzed for the Central Region. Due to a large number of missing data in MENG (multiengine aircraft), this variable was eliminated from the study for the Central Region. According to the logistic regression results, as shown in table 6, the combination of LCOND, IMC, DESCENT, APPLDG, MANV, and YEAR variables, as defined below, were found to be highly statistically significant coefficients in the Central Region. As shown in table 6, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 124). The model correctly classified 91% of the cases.

- Lighting Condition (LCOND)—As expected, the coefficient of 0.478 for lighting conditions (LCOND) was positive and significant, indicating that a darker environment was associated with an increased probability of a fatal accident. Odds ratio of 1.613 for lighting condition variable suggests that although a one-step change in lighting condition (e.g., from dawn to night) results in a small change in probability, the change from daylight to night (three-step change) results in a substantial increase in the likelihood of a fatal accident.

- Instrument Meteorological Condition (IMC)—IMC means that the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 1.917 for IMC suggested that a low- or bad-visibility environment increased the probability of the accident to be fatal. In addition, the odds ratio of 7.444 for IMC was the second highest (IMC being highest) for all the variables, indicating that IMC was a major contributor in fatal GA accidents in the Central Region.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributes to fatal GA accident. Out of the six, three variables were found to be significant contributor in fatal GA accidents: DESCENT, APPLDG, and MANV.

  Negative and significant coefficient of -2.517 for APPLDG (approach or landing) implied that airplanes in approach and landing phases of flight were less likely to be involved in fatal accidents.

  DESCENT and MANV had a positive and significant coefficient of 3.192 and 1.864 respectively, which implied that an airplane on the descent and maneuvering stages of flight is much more likely to be involved in fatal accidents. DESCENT has the highest odds ratios of 24.347, and MANV has third-highest odds ratio of 6.451, implying descent and maneuvering phases of flight are among major contributors in fatal GA accidents in the Central Region.

- Year of Accidents (YEAR)—The YEAR variable was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested that there was a downward trend in GA accidents—over the 28-year sample period, the probability of an accident becoming fatal significantly decreased.

Table 6. Logistic Regression Parameter Estimates and Odds Ratios for the Central Region

Variable	Coefficient	Significance	Changes in Odds
FPF	-0.368	0.465	0.692
LCOND	0.478**	0.001	1.613
IMC	1.971**	0.002	7.181
XCNT	0.205	0.619	1.227
LogWIND	-0.254	0.571	0.776
MENG	0.161	0.807	1.175

Table 6. Logistic Regression Parameter Estimates and Odds Ratios for the Central Region (continued)

Variable	Coefficient	Significance	Changes in Odds
TYPR	0.855	0.076	2.351
SIC	0.660	0.156	1.934
SBLT	-2.536	0.085	0.079
SHARN	0.366	0.309	1.441
MED	0.026	0.935	1.026
GENDER	0.993	0.174	2.698
LogAGE	1.785	0.218	5.960
LogTTIME	0.288	0.527	1.333
TFT	0.882	0.088	2.415
LMF	0.254	0.515	1.290
LMH	-20.607	0.999	0.000
TAXI	-1.633	0.208	0.195
TAKEOFF	-0.451	0.390	0.637
CLIMB	0.048	0.967	1.049
DESCENT	3.192**	0.002	24.347
APPLDG	-2.517**	0.000	0.081
MANV	1.864**	0.000	6.451
YEAR	-0.114**	0.001	0.892
Chi-square of the model = 124			Overall correctly classified cases = 91%

3.5 REGION 5—GREAT LAKES.

This section discusses the variables analyzed for the Great Lakes Region. According to the logistic regression results, as shown in table 7, the combination of IMC, SIC, SBLT, GENDER, TAXI, TAKEOFF, APPLDG, MANV, and YEAR variables, as defined below, were found to be highly statistically significant coefficients in the Great Lakes Region. As shown in table 7, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 444). The model correctly classified 89.6% of the cases.

- Instrument Meteorological Condition (IMC)—IMC means the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 1.842 for IMC suggested that a low- or bad-visibility environment increased the probability of a fatal accident. In addition, the odds ratio of 6.309 for IMC was the highest among all the variables indicating that IMC was a major contributor in fatal GA accidents in the Great Lakes Region.

- Gender—As implied by the positive and significant coefficients of 0.817 for GENDER, the gender of the pilot has impact on the probability of an accident to be fatal. This

indicated that female pilots were more likely to be involved in fatal GA accidents in the Great Lakes Region.

- Seat Belts (SBLT)—SBLT indicates whether the pilot was wearing a seat belt at the time of the accident. As suggested by the negative and highly statistically significant coefficient of -1.86 and very low odds ratio of 0.156, wearing a seat belt considerably reduced the probability of an accident to be fatal.

- Second Pilot Onboard (SIC)—Another counterintuitive result was the positive and significant coefficient of 0.656 for SIC, which indicated that when a copilot was onboard, it resulted in a more fatal accident. Conventional wisdom suggests that a copilot onboard would help the pilot in command in the case of an unexpected emergency. However, for this help to be constructive, GA airplane pilots should understand how to properly use available in-flight human resources. Without such an understanding, a copilot onboard the GA airplane during an emergency situation would only make the situation worse, possibly interfering with the flight controls or influencing the ability of the pilot in command to resolve the situation.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributes to fatal accidents. Out of the six, four variables were found to be significant contributors in fatal GA accidents: TAXI, TAKEOFF, APPLDG, and MANV.

  Negative and significant coefficients of TAXI, TAKEOFF, and APPLDG (approach or landing) imply that airplanes in taxi, takeoff, and approach/landing phases of flight are less likely to be involved in fatal accidents.

  MANV had a positive and significant coefficient of 1.134, which implied that an airplane in the maneuvering stage of flight was much more likely to be involved in a fatal accident. MANV had the second highest odds ratios of 3.107 (IMC being highest), indicating that the maneuvering phases were major contributors in fatal GA accidents in the Great Lakes Region.

- Year of Accidents (YEAR)—The YEAR variable was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested there was a downward trend in GA accidents—over the 28-year sample period, the probability of an accident becoming fatal significantly decreased.

Table 7. Logistic Regression Parameter Estimates and Odds Ratios for the Great Lakes Region

Variable	Coefficient	Significance	Changes in Odds
FPF	-0.046	0.842	0.955
LCOND	0.073	0.359	1.076
IMC	1.842**	0.000	6.309
XCNT	0.290	0.117	1.337

Table 7. Logistic Regression Parameter Estimates and Odds Ratios for the Great Lakes Region (continued)

Variable	Coefficient	Significance	Changes in Odds
LogWIND	-0.229	0.282	0.795
MENG	0.401	0.127	1.493
TYPR	0.145	0.541	1.156
SIC	0.656**	0.003	1.926
SBLT	-1.86*	0.018	0.156
SHARN	-0.053	0.746	0.948
MED	0.150	0.335	1.162
GENDER	0.817*	0.048	2.264
LogAGE	0.709	0.331	2.032
LogTTIME	0.164	0.397	1.178
TFT	0.152	0.505	1.164
LMF	0.280	0.154	1.323
LMH	-0.840	0.435	0.432
TAXI	-1.92**	0.001	0.147
TAKEOFF	-1.249**	0.000	0.287
CLIMB	0.094	0.847	1.099
DESCENT	1.580	0.054	4.854
APPLDG	-2.224**	0.000	0.108
MANV	1.134**	0.000	3.107
YEAR	-0.114**	0.000	0.892
Chi-square of the model = 444			Overall correctly classified cases = 89.6%

3.6 REGION 6—NORTHWEST MOUNTAIN.

This section discusses the variables analyzed for the Northwest Mountain Region. Due to a large number of missing data in MENG (multiengine aircraft), this variable was eliminated from the study for Northwest Mountain Region. According to the logistic regression results, as shown in table 8, the combination of FPF, APPLDG, and YEAR variables, as defined below, were found to be highly statistically significant coefficients in Northwest Mountain Region. As shown in table 8, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 126). The model correctly classified 86.9% of the cases.

- Flight Plan (FPF)—FPF indicates whether visual flight rules (VFR), instrument flight rules (IFR), or VFR/IFR flight plans were filed and resulted in being significant contributors in fatal GA accidents in the Northwest Mountain Region. The odds ratio of 3.697 and significance level of 1% (as indicated by **) indicates that the one-step change in FPP resulted in a substantial increase in the likelihood of a fatal accident.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributed to fatal accidents. Out of the six, only one variable was found to be significant: APPLDG.

  Negative and significant coefficients of -1.2319 for APPLDG (approach or landing) imply that airplanes in takeoff or approach/landing phases of flight are less likely to be involved in fatal accidents.

- Year of Accidents (YEAR)—The YEAR variable was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested that there was a downward trend in GA accidents—over the 28-year sample period, the probability of an accident becoming fatal significantly decreased.

Table 8. Logistic Regression Parameter Estimates and Odds Ratios for the Northwest Mountain Region

Variable	Coefficient	Significance	Changes in Odds
FPF	1.3074**	0.000	3.697
LCOND	0.251	0.064	1.285
IMC	0.661	0.136	1.937
XCNT	0.647	0.112	1.910
LogWIND	0.547	0.119	1.729
TYPR	-0.614	0.172	0.541
SIC	0.513	0.232	1.670
SBLT	-23.866	0.999	0.000
SHARN	0.159	0.659	1.173
MED	-0.426	0.129	0.653
GENDER	-1.293	0.232	0.274
LogAGE	1.659	0.268	5.255
LogTTIME	-0.381	0.297	0.683
TFT	-0.286	0.542	0.752
LMF	-0.220	0.579	0.802
LMH	0.484	0.675	1.622
TAXI	-20.480	0.998	0.000
TAKEOFF	-0.723	0.236	0.485
CLIMB	-20.210	0.999	0.000
DESCENT	1.994	0.111	7.344
APPLDG	-1.2319**	0.000	0.292
MANV	0.699	0.300	2.012
YEAR	-0.1323**	0.000	0.876
Chi-square of the model = 126		Overall correctly classified cases = 86.9%	

3.7 REGION 7—NEW ENGLAND.

This section discusses the variables analyzed for the New England Region. According to the logistic regression results, as shown in table 9, the combination of IMC, XCNT, TYPR, LMF, TAXI, TAKEOFF, APPLDG, MANV, and YEAR variables, as defined below, were found to be highly statistically significant coefficients in the New England Region. As shown in table 9, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 331). The model correctly classified 89.9% of the cases.

- Instrument Meteorological Condition (IMC)—IMC means the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 1.20 for IMC suggested that a low- or bad-visibility environment increased the probability of a fatal accident. In addition, the odds ratio of 3.319 for IMC was the highest for all the variables, indicating that IMC was a major contributor in fatal GA accidents in the New England Region.

- Cross-Country Flight (XCNT)—The variable XCNT indicates whether an airplane was on a cross-country flight at the time of the accident. The positive and significant coefficient of 0.412 for XCNT indicated that cross-country flights have increased the probability to be involved in a fatal GA accident.

- Pilot's Type Rating (TYPR)—TYPR variable indicates if a pilot was type-rated at the airplane involved in the accident. Positive and significant coefficient of 0.484 showed counterintuitive results of high probability for an aircraft to encounter a fatal accident if it was flown by a type-rated pilot.

- Pilot's Flight Time Over the Last 30 Days (LMF)—The LMF mock variable indicates that the airplane pilot flew less than 5 hours in the 30 days preceding the accident, respectively. This variable was included in the analysis to examine if less-practiced pilots (with less than 5 hours in 30 days) have a higher probability of a fatal accident. The positive and significant coefficient of 0.459 for LMF variable indicated that less-practiced pilots are more likely to be involved in a fatal accident than pilots with more normal (5 to 100 hours) flight schedules in the preceding 30 days.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributed to fatal accidents. Out of the six, four variables were found to be significant contributors in fatal GA accidents: TAXI, TAKEOFF, APPLDG, and MANV.

  The negative and significant coefficients of TAXI, TAKEOFF, and APPLDG (approach or landing) implied that airplanes in taxi, takeoff, or approach/landing phases of flight were less likely to be involved in fatal accidents.

  MANV had the positive and significant coefficient of 0.647, which implied that an airplane in the maneuvering stage of flight is more likely to be involved in a fatal accident.

- Year of Accidents (YEAR)—The YEAR variable was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested there was a downward trend in GA accidents—over the 28-year sample period, the probability of an accident becoming fatal significantly decreased.

Table 9. Logistic Regression Parameter Estimates and Odds Ratios for the New England Region

Variable	Coefficient	Significance	Changes in Odds
FPF	0.154	0.467	1.167
LCOND	0.173	0.052	1.189
IMC	1.2**	0.000	3.319
XCNT	0.412*	0.043	1.510
LogWIND	0.098	0.608	1.103
MENG	0.094	0.762	1.098
TYPR	0.484*	0.048	1.623
SIC	0.334	0.146	1.396
SBLT	-0.760	0.437	0.468
SHARN	-0.191	0.279	0.826
MED	-0.155	0.305	0.857
GENDER	-0.312	0.500	0.732
LogAGE	0.650	0.417	1.915
LogTTIME	-0.116	0.552	0.890
TFT	-0.108	0.657	0.897
LMF	0.459*	0.022	1.583
LMH	-0.083	0.905	0.920
TAXI	-1.427*	0.025	0.240
TAKEOFF	-0.901**	0.002	0.406
CLIMB	-0.362	0.380	0.696
DESCENT	1.001	0.343	2.721
APPLDG	-2.065**	0.000	0.127
MANV	0.647**	0.009	1.910
YEAR	-0.117**	0.000	0.890
Chi-square of the model = 331			Overall correctly classified cases = 89.9%

3.8 REGION 8—SOUTHERN.

This section discusses the variables analyzed for the Southern Region. According to the logistic regression results, as shown in table 10, the combination of FPF, LCOND, IMC, MENG, TYPR, SBLT, SHARN, TAKEOFF, DESCENT, APPLDG, MANV, and YEAR variables, as defined below, were found to be highly statistically significant coefficients in the Southern Region. As shown in table 10, goodness of fit for the model was statistically reliable in distinguishing

between fatal and nonfatal accidents (Chi-square = 492). The model correctly classified 88.7% of the cases.

- Flight Plan (FPF)—FPF indicates if VFR, IFR, or VFR/IFR flight plans were filed and resulted in being significant contributors in fatal GA accidents in the Southern Region. The odds ratio of 1.464 and significance level of 5% (as indicated by *) indicated that the one-step change in FPF would result in a substantial increase in the likelihood of a fatal accident.

- Lighting Condition (LCOND)—As expected, the coefficient of 0.332 for lighting conditions (LCOND) was positive and significant, indicating that a darker environment was associated with increased probability of an accident to be fatal. The odds ratio of 1.394 for the lighting condition variable suggested that, although a one-step change in lighting condition (e.g., from dawn to night) resulted in a small change in probability, the change from daylight to night (a three-step change) resulted in a substantial increase in the likelihood of a fatal accident.

- Instrument Meteorological Condition (IMC)—IMC means the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 1.778 for IMC suggested that a low- or bad-visibility environment increased the probability of a fatal accident. In addition, the odds ratio of 5.920 for IMC was the highest for all the variables, indicating that IMC was a major contributor in fatal GA accidents in the Southern Region.

- Multiengine Aircraft (MENG)—MENG indicates whether an airplane in an accident had more than one engine. The positive and significant coefficient of 0.478 for MENG implied that a multiengine airplane had more probability to be involved in a fatal accident. Although more than one engine installed on an airplane decreases the likelihood of total loss of power and offers safety advantages (especially in the en route phase of flight), small multiengine airplanes are safer only if the pilot fully understands the real options offered by the second engine in the takeoff and approach phases. When a light, twin-engine airplane loses one engine, significantly more than half the climb performance disappears. Multiengine GA airplane pilots who do not understand the magnitude of decreased performance and fly close to the ground are in danger of being involved in a fatal accident [8]. Apparently, the enhancement of safety that comes from the second engine is somewhat diminished by the increased complexity of handling the airplane when one engine fails; and the pilot's false sense of security, in comparison, makes the second engine seem to be an insignificant factor in terms of the probability of a fatal accident.

- Pilot's Type Rating (TYPR)—The TYPR variable indicates whether a pilot was type-rated at the airplane involved in the accident. The positive and significant, but small, coefficient of 0.505 showed that type-rated pilots are likely to be involved in fatal GA accidents in the Southern Region.

- Seat Belts (SBLT)—SBLT indicates whether the pilot was wearing a seat belt at the time of the accident. As suggested by the negative and highly statistically significant coefficient of -1.385 and very low odds ratio of 0.250, wearing a seat belt considerably reduced the probability of an accident to be fatal.

- Shoulder Harness (SHARN)—SHARN indicates whether the pilot was wearing a shoulder harness at the time of the accident. The negative and significant coefficient of -0.332 for SHARN suggested a reduction of the probability of being involved in fatal accidents for pilots wearing a shoulder harness.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if phase of flight contributed to fatal GA accidents. Out of the six, four variables were found to be significant contributors in fatal GA accidents: TAKEOFF, DESCENT, APPLDG, and MANV.

  Negative and significant coefficients of TAKEOFF and APPLDG (approach or landing) implied that airplanes in takeoff or approach/landing phases of flight are less likely to be involved in fatal accidents.

  DESCENT and MANV have a positive and significant coefficient of 1.648 and 1.571, respectively, which implies that an airplane on the descent or maneuvering stage of flight is much more likely to be involved in a fatal accident. DESCENT has the highest odds ratios of 5.195, and MANV has third-highest odds ratio of 4.810, implying decent and maneuvering phases of flight were major contributors in fatal GA accidents in the Southern Region.

- Year of Accidents (YEAR)—The variable YEAR was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested there was a downward trend in GA accidents—over the 28-year sample period, the probability of an accident becoming fatal significantly decreased.

Table 10. Logistic Regression Parameter Estimates and Odds Ratios for the Southern Region

Variable	Coefficient	Significance	Changes in Odds
FPF	0.381*	0.027	1.464
LCOND	0.332**	0.000	1.394
IMC	1.778**	0.000	5.920
XCNT	0.116	0.480	1.123
LogWIND	-0.008	0.969	0.992
MENG	0.478*	0.024	1.613
TYPR	0.505**	0.005	1.657
SIC	0.346	0.056	1.414
SBLT	-1.385**	0.009	0.250
SHARN	-0.332*	0.024	0.717

Table 10. Logistic Regression Parameter Estimates and Odds Ratios for the Southern Region (continued)

Variable	Coefficient	Significance	Changes in Odds
MED	-0.043	0.723	0.958
GENDER	0.003	0.993	1.003
LogAGE	0.880	0.147	2.412
LogTTIME	-0.226	0.129	0.798
TFT	-0.032	0.871	0.969
LMF	0.326	0.067	1.385
LMH	0.231	0.598	1.259
TAXI	-19.708	0.997	0.000
TAKEOFF	-0.554*	0.016	0.574
CLIMB	-0.111	0.781	0.895
DESCENT	1.648*	0.011	5.195
APPLDG	-1.681**	0.000	0.186
MANV	1.571**	0.000	4.810
YEAR	-0.067**	0.000	0.935
Chi-square of the model = 492			Overall correctly classified cases = 88.7%

3.9 REGION 9—EASTERN.

This section discusses the variables analyzed for the Eastern Region. According to the logistic regression results, as shown in table 11, the combination of LCOND, IMC, APPLDG, MANV, and YEAR variables, as defined below, were found to be highly statistically significant coefficients in the Eastern Region. As shown in table 11, goodness of fit for the model was statistically reliable in distinguishing between fatal and nonfatal accidents (Chi-square = 280). The model correctly classified 89.9% of the cases.

- Lighting Condition (LCOND)—As expected, the coefficient of 0.39 for lighting conditions (LCOND) was positive and significant, indicating that a darker environment was associated with increased probability of a fatal accident. The odds ratio of 1.477 for the lighting condition variable suggested that, although a one-step change in lighting condition (e.g., from dawn to night) resulted in a small change in probability, the change from daylight to night (a three-step change) resulted in a substantial increase in the likelihood of a fatal accident.

- Instrument Meteorological Condition (IMC)—IMC means the flight was conducted in a low- or bad-visibility environment. The positive and significant coefficient of 2.093 for IMC suggested that a low- or bad-visibility environment increased the probability of a fatal accident. In addition, the odds ratio of 8.111 for IMC was the highest for all the variables, indicating that IMC was a major contributor in fatal GA accidents in the Eastern Region.

- Phase of Flight—Six phase-of-flight variables were included in the analysis to examine if the phase of flight contributed to fatal accidents. Out of the six, two variables were found to be significant contributors in fatal GA accidents: APPLDG and MANV.

  Negative and significant coefficients of -1.454 for APPLDG (approach or landing) implied that airplanes in approach/landing phases of flight were less likely to be involved in fatal accidents.

  MANV had the positive and significant coefficient of 1.332, which implied that an airplane in the maneuvering phase of flight is more likely to be involved in a fatal accident. MANV had the second-highest odds ratio of 3.788 (IMC being highest), indicating that MANV was a significant contributor in fatal GA accidents in the Eastern Region.

- Year of Accidents (YEAR)—The YEAR variable was added to capture the time effect on fatalities in GA accidents. Its negative and significant coefficient suggested there was a downward trend in GA accidents—over the 28-year sample period, the probability of an accident becoming fatal significantly decreased.

Table 11. Logistic Regression Parameter Estimates and Odds Ratios for the Eastern Region

Variable	Coefficient	Significance	Changes in Odds
FPF	-0.114	0.682	0.892
LCOND	0.39**	0.000	1.477
IMC	2.093**	0.000	8.111
XCNT	0.312	0.186	1.367
LogWIND	0.368	0.132	1.444
MENG	0.387	0.236	1.472
TYPR	-0.070	0.794	0.932
SIC	0.483	0.084	1.621
SBLT	-0.738	0.603	0.478
SHARN	-0.252	0.229	0.777
MED	0.051	0.776	1.052
GENDER	0.545	0.254	1.725
LogAGE	0.900	0.327	2.461
LogTTIME	-0.116	0.617	0.890
TFT	-0.106	0.700	0.899
LMF	0.376	0.115	1.456
LMH	-0.140	0.849	0.869
TAXI	-19.640	0.998	0.000
TAKEOFF	-0.056	0.851	0.945
CLIMB	-0.504	0.539	0.604
DESCENT	1.325	0.175	3.764

Table 11. Logistic Regression Parameter Estimates and Odds Ratios for the Eastern Region (continued)

Variable	Coefficient	Significance	Changes in Odds
APPLDG	-1.454**	0.000	0.234
MANV	1.332**	0.000	3.788
YEAR	-0.115**	0.000	0.892
Chi-square of the model = 280			Overall correctly classified cases = 88.9%

4. CONCLUSIONS.

General aviation (GA) is accountable for 82% of total air transport-related accidents and for 83% of all air transport-related fatalities. The identification of factors that cause or contribute to fatal accidents is important for the GA community because it will help prevent or minimize the impact of controllable factors and decrease the number of fatalities in GA accidents.

The results from the logistic regression identified factors that increased the probability of a fatal GA accident. While some of the factors (such as night or low-visibility conditions) cannot be controlled by GA airplane pilots, others (such as flying too much or not enough in the preceding 30 days or having a copilot onboard) can be taken into consideration. Whereas flying without a copilot onboard is probably not a feasible option, Crew Resource Management training will help GA airplane pilots to minimize the negative impact of this factor. In addition, emphasis on all contributing factors to fatal GA accidents during training and flight planning may reduce the number of fatal accidents in GA.

4.1 REGION 1—WESTERN PACIFIC.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the Western Pacific Region: flying at night; flying in instrument metrological conditions (IMC); flying with a copilot onboard; the pilots having less than 5 hours of flight time over the preceding 30 days; and takeoff, approach/landing, and maneuvering phases of flight.

4.2 REGION 2—SOUTHWEST.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the Southwest Region: flying at night; flying in IMC; pilot flying without wearing a seat belt; pilot flying without wearing a shoulder harness; and takeoff/approach or landing phases of flight.

4.3 REGION 3—ALASKAN.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the Alaskan Region: flying in IMC; and takeoff/approach or landing phase of flight.

4.4 REGION 4—CENTRAL.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the Central Region: flight filed with instrument flight rules (IFR); flying at night; and descent, approach/landing, and maneuvering phases of flight.

4.5 REGION 5—GREAT LAKES.

The following factors were found statistically to be significant in increasing the probability that a GA flight will be involved in a fatal accident in the Great Lakes Region: flying in IMC; flying with a copilot onboard; pilot flying without wearing a seat belt; gender of the pilot; and taxi, takeoff, approach/landing, and maneuvering phases of flight.

4.6 REGION 6—NORTHWEST MOUNTAIN.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the Northwest Mountain Region: flight filed with IFR or visual flight rules; and approach/landing phase of flight.

4.7 REGION 7—NEW ENGLAND.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the New England Region: flying in IMC; performing a cross-country flight; type-rated pilots; pilots having less than 5 hours of flight time over the preceding 30 days; and taxi, takeoff, approach/landing, and maneuvering phases of flight.

4.8 REGION 8—SOUTHERN.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the Southern Region: flight filed with IFR; flying at night; flying in IMC; flying in multiengine aircraft; type-rated pilots; pilot flying without wearing a seat belt; pilot flying without wearing a shoulder harness; and takeoff, descent, approach/landing, and maneuvering phases of flight.

4.9 REGION 9—EASTERN.

The following factors were found to be statistically significant in increasing the probability that a GA flight will be involved in a fatal accident in the Eastern Region: flying at night; flying in IMC; and approach/landing and maneuvering phases of flight.

5. REFERENCES.

1. Bazargan, M. and Guzhva, V., "Factors Contributing to Fatalities in General Aviation," *World Review of Intermodal Transportation Research*, Vol. 1, No. 2, 2007, pp. 170-182.

2. Bazargan, M. and Guzhva, V., "Impact of Gender, Age and Experience of Pilots on General Aviation Accidents," *Accident Analysis & Prevention*, Vol. 43, No. 3, May 2011, DOI: 10.1016/j.aap.2010.11.023, pp. 962-970.

3. National Transportation Safety Board, NTSB Form 6120.1; "Pilot/Operator Aircraft Accident/Incident Report," http://www.ntsb.gov/doclib/forms/6120_1web_nopwx.pdf

4. Bazargan, M., Kosalim, H., Williams, M., and Singh, A., "Comprehensive Analysis of General Aviation Accident" (Vols. 1 and 2), FAA report DOT/FAA/AR-12/2; March 2012.

5. Department of Transportation, Federal Aviation Administration, Title 14 Code of Federal Regulation Part 91—Generated Operating and Flight Rules, U.S. Federal Register, U.S. Government Printing Office.

6. Statistical Package for the Social Sciences, http://www.-01.ibm.com/software/analytics/spss

7. Hair, J., Black, W., Babin, B., Anderson, R., and Tatham, R., *Multivariate Data Analysis, Sixth Edition*, Prentice Hall, 2005.

8. Aarons, R.N., "Always Leave Yourself an Out," *Business and Commercial Aviation*, Vol. 33, No. 1, July 1973.

APPENDIX A—STATISTICAL MODEL DESCRIPTION

Logistic regression model is estimated as follows:

$$\begin{aligned} FATAL_i = {} & a + b_1 FPLV_i + b_2 FPF + b_4 LCOND_i + b_5 IMC_i + \\ & b_6 XCNT_i + b_7 Log(WIND_i) + b_8 RLG_i + b_9 MENG_i + b_{10} TYPR_i + \\ & b_{11} SIC_i + b_{12} SBLT_i + b_{13} SHARN_i + b_{14} MED_i + b_{15} GENDER_i + \\ & b_{16} Log(AGE_i) + b_{17} Log(TTIME_i) + b_{18} TFT_i + b_{19} LMF_i + \\ & b_{20} LMH_i + b_{21} TAXI_i + b_{22} TAKEOFF_i + b_{23} CLIMB_i + \\ & b_{24} DESCENT_i + b_{25} APPLDG_i + b_{26} MANV_i + b_{27} YEAR_i + e_i \end{aligned} \qquad \text{(A-1)}$$

where:

FATAL is the fatal accident (dependant variable);

FPF is the visual flight rule (VFR), instrument flight rule (IFR) or VFR/IFR flight plan;

LCOND the light condition variable;

IMC is the instrument meteorological condition variable;

XCNT is the cross-country flight variable;

WIND is the wind velocity in the area;

RLG is the retractable landing gear variable;

MENG is the multiengine airplane variable;

TYPR is the pilot’s type-rating variable;

SIC is the second pilot onboard variable;

SBLT is the seat belt variable;

SHARN is the shoulder harness variable;

MED is the type of medical certificate variable;

GENDER is the gender variable;

AGE is the pilot’s age in years;

TTIME is the pilot’s total flight experience in hours;

TFT indicates if the pilot had total flight experience between 50 and 300 hours;

LMF indicates if the pilot had less than 5 hours of flight time over the last 30 days;

LMH indicates if the pilot had more than 100 hours of flight time over the last 30 days;

TAXI indicates if the airplane was taxiing at the time of the accident;

TAKEOFF indicates if the airplane was taking off at the time of the accident;

CLIMB indicates if the airplane was climbing at the time of the accident;

DESCENT indicates if the airplane was descending at the time of the accident;

APPLDG indicates if the accident happened during approach and landing;

MANV indicates if the accident happened during maneuvering;

YEAR indicates the period when the accident occurred;

e is a prediction error (residual)