Cross-Country VFR Accidents: Pilot and Contextual Factors

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Abstract

Background: General Aviation (GA) accidents involving 'VFR into IMC' continue to be a major source of fatalities with a fatality rate more than four times greater than for GA accidents in general. There has been much speculation and little solid evidence on the causes of these accidents**. Methods**: We have designed a broad program of research into the causes of cross-country weather-related accidents including a detailed analysis of air accidents in New Zealand between 1988 and 2000. There were 1308 reported occurrences in this period. We examined in detail 77 accidents where it could be determined that the aircraft was on a cross-country flight. **Results**: In our first analysis we compared the characteristics of crashes which occurred in response to externally-driven failures requiring immediate action with crashes where the pilot maintained on-going control over the aircraft. Clear differences were found for visibility, altitude, crash severity and for several pilot characteristics. These differences are highly consistent with those found for previous research on pilot characteristics and accident involvement. In the second analysis we made comparisons between the weather-related and non weather-related crashes in the on-going control group and between sub-categories of weather-related crashes. **Conclusions**: These data show that weather-related crashes occur further into the flight and closer to the planned destination than other kinds of cross-country crashes in GA. Pilots involved in these crashes are younger and have more recent flight time than pilots involved in other crashes. Their increased involvement cannot be explained simply by exposure (flight-time) but must be due to other factors.

The accident rate in general aviation (GA) continues to be substantially higher than that in other sectors of aviation (10). Whilst the GA accident rate appears to be declining in some countries such as the United States (1) the rate appears to be static or even increasing in others such as Australia and New Zealand (6). Although only accounting for a small proportion of GA accidents, weather-related accidents continue to have a very high fatality rate with three out of four such accidents in the United States involving a fatality (7).

Speculation on the causes of these fatal accidents has involved such psychological factors as over-confidence (9) faulty risk-perception (5) and lack of awareness (4). Several explanations focus on the idea that as the time and distance into a flight increases so might the pilot's desire to continue to the planned destination. This attraction, it is argued, may adversely affect the pilot's appraisal of the flight circumstances leading to risky decisions. Psychological theories such as the theory of sunk costs (2) provide solid empirical evidence for the suggestion that commitment to a chosen course of action increases with continued investments of time or money. A pilot in the latter stages of a cross-country flight has certainly invested plenty of both.

To the best of our knowledge no one has investigated GA crashes in terms of how far into planned flights the crashes occurred. It is important to determine if there is any evidence for increasing boldness or risk-taking as flights progress. Our main aim was to examine the records of GA flights which had crashed whilst conducting planned cross-country flights. The views discussed above would suggest that as long as the flights remained under the control of the pilot there would be an increasing probability of crashes occurring later in the flight. To evaluate this hypothesis requires a comparable sample of crashes whose occurrence is largely dictated by events outside the pilots’ control and therefore beyond the reach of any possible psychological factors. Such crashes generally occur in association with sudden and unexpected engine or systems failures. If psychological pressures such as sunk costs or attraction to a goal are determinants of crashes involving poor decision making then these crashes should occur significantly later in the flight than crashes due to mechanical or systems failures.

METHODS

An electronic database of all reported aircrashes in New Zealand was developed from data provided by the Civil Aviation Authority of New Zealand (CAA) and the Transport Accident Investigation Commission of New Zealand (TAIC). The basic database supplied by the CAA covered the years 1988 to 2000 (inclusive). The TAIC database covered the years 1988-1994. The two databases were manually merged to form one integrated database. The database contained fields covering the details of the crash (date, location, phase of flight etc), pilot (name, age, gender, total flight hours etc), operation (number of crew, VFR/IFR etc), aircraft (type, registration number, number of engines etc) and the outcome of the crash (severity of damage, injuries etc). There were 1308 cases recorded in the database. Unfortunately many of the fields were blank as the information had not been entered by the accident investigators. Some additional information was obtained from written TAIC reports covering some air transport operations and cases of greater public significance.

An initial search of the database was made to locate all potential cases involving a crash during a planned cross-country (i.e. where the intended destination was at least 25nm from the point of departure). All flights involving aerial work such as logging, hunting, firefighting or aerial application were excluded unless the aircraft was on a cross-country flight to or from the place of work at the time of the crash.

This initial search yielded 238 potential cross-country crashes. A case was defined as a cross-country flight if there was information in the database to indicate that the departure and intended destination were at least 25nm apart or if the distance between the crash location and either the departure or intended destination was at least 25nm. To do this required the calculation of surface distances between points specified by Lat and Long coordinates. We developed the following formula that takes the curvature of the earth into account but assumes the earth to be a perfect sphere:

$$\text{Distance in nm} = \sqrt{60\left(Lat_1 - Lat_2\right)^2 + \left[60\left(Lon_1 - Lon_2\right)Cos\left(\frac{Lat_1\pi}{180}\right) + Cos\left(\frac{Lat_2\pi}{180}\right)\right]^2}$$

The Microsoft Excel™ expression of the formula is given in Appendix 1. Application of this formula to the 238 possible cases yielded 77 confirmed cases that met the criteria. For most of the remaining cases either the departure point or intended destination were not recorded in the database so it was not possible to confirm the cross-country status of these flights.

Each of the 77 cases was coded in terms of whether the pilot was reacting to an immediate and unplanned event, such as a sudden engine failure, requiring urgent action or whether the pilot was in on-going control over the aircraft and its systems at the time of the crash. The first category (n = 31) was labelled ‘Acts of God’ (AOG) and was almost entirely made up of engine failures (n = 23). The second category (n = 46) was labelled ‘In-Flight Volitional’ (IFV) which included both weather-related crashes (n = 28) and loss-of-control and collision crashes (n = 14). The authors coded the cases separately. Both authors were in agreement on 91% of the cases. Differences were resolved by discussion.

RESULTS

Distance of Crash into Flight

The average distance into the flight when the crash occurred was 78.1 nm for the AOG group compared to72.9 nm for the IFV group. This difference was not statistically significant ($F(1,75) = .072$, $p = .79$). However, when the IFV group are subdivided into weather-related and loss-of-control crashes (see Table 1) we find that there is a substantial difference in the average distance from departure point to crash of 92.5nm for the weather-related crashes compared to 49.7nm for the loss-of-control crashes. Comparing the three groups (AOG crashes, weather-related IFV, loss-of-control IFV) shows a significant difference in departure-crash distances (χ^2 (2) = 7.2, $p < .03$) and a significant difference in the departure-crash distance as a percentage of the distance to the intended destination ($F(2,59) = 3.4$, $p = .04$).

(Table 1 about here)

Crash Characteristics

There was a statistically significant difference in the height above sea level of the crash site for the two categories with the IFV crashes occurring at a mean 2,970ft amsl compared to 150ft amsl for the AOG crashes ($F(1,20) = 6.3$, $p = .02$). There was also a marginally significant difference ($F(1,28) = 8.3$, $p = 0.07$) in the estimated visibility at the time of the crash which was over 20km for all the AOG crashes and an average of 5-20km for the IFV crashes. Seven of the IFV crashes were coded as occurring in visibility below 5km.

The two groups of crashes are significantly different in their injury outcomes. There were over twice the number of fatalities (1.6 versus .68) in the IFV crashes compared to the AOG crashes ($F(1,75) = 3.83$, $p = .05$). The same was true for the incidence of fatal and serious injuries combined ($F(1,75) = 4.6$, $p = .036$). These findings are consistent with previous findings on the very high incidence of serious injury outcomes associated with both loss-of-control and weather-related crashes in GA.

Pilot Characteristics

The mean age of the pilots involved in IFV crashes was 37.8 years compared to 47 yrs for pilots involved in AOG crashes. This difference of 9.2 years is statistically significant ($F(1,43) = 3.9$, $p = .05$). There was a large difference in the mean hours flown in the previous 90 days with the IFV group having flown 59.8 hours compared to 31.9 for the AOG group. This difference just failed to reach the usual criterion of statistical significance ($F(1,54) = 3.7$, $p = .06$). There were no statistically significant differences in terms of any of the other pilot characteristics such as total flight hours etc.

Characteristics of 'IFV' Crashes

The 46 crashes in this group could be divided into 3 categories. The largest group involved weather-related crashes (n = 28), the next group involved loss-of-control or collisions (n = 14) and the smallest group involved fuel mismanagement (n = 4). The distance into the flight where the crash occurred both in nautical miles ($\chi^2(1) = 6.6$, $p = .01$) and as a percentage of the intended flight ($\chi^2(1) = 6.2$ $p = .01$) were significantly different between the weather-related and the loss-of-control/collision groups. The weather-related group were more likely to have had a weather briefing than the loss-of-control/collision group ($\chi^2(1) = 6.4$, $p = .01$). The fuel mismanagement group was ignored due to the very low number of cases.

The weather-related crashes could be further sub-divided into three types. The first group comprised 'classic' VFR into IMC crashes. The second group were crashes which occurred whilst carrying out a precautionary landing. The third group were other weather-related crashes involving factors such as turbulence and downdraughts. The mean height above sea level of the crash site was greatest for the ‘other weather-related’ group (5300 ft amsl) compared to 2200 ft amsl for the ‘classic’ VFR into IMC’ crashes. The small number of cases for which this information was available precludes an analysis of statistical significance.

There was a highly significant difference between these sub-groups in terms of crash outcome (χ^2 (2) = 12.25, p = .002). Whilst there were 6 fatal accidents in both the ‘classic’ and ‘other’ categories there were none in the ‘precautionary landing’ group. In percentage terms, the proportion of fatal crashes was greatest for the ‘other’ group (86%) compared to 50% for the ‘classic’ VFR into IMC crashes and 0% for the precautionary landing group.

DISCUSSION

Our analysis of cross-country general aviation crashes has confirmed previous findings that crashes that occur whilst the pilot is voluntarily directing the course of the flight have disproportionately serious outcomes compared to other types of crashes. We prefer not to call these decisional errors as the processes responsible for these outcomes have not yet been determined. The problems may be due to a number of factors including decision making, risk assessment and situational awareness. We are currently conducting a program of laboratory research designed to illuminate these issues. The analysis also shows the clear survival value of the precautionary landing which were invariably non-fatal.

Since weather-related crashes have been commonly ‘explained’ in terms of a tendency to unwisely continue flights on into deteriorating conditions we expected to see a significant difference between the distances into a flight where these crashes occurred compared to a sample of crashes precipitated by sudden engine or systems failure. Our data show that the weather-related crashes occurred further away from the point of departure and closer to the intended destination than other types of crashes.

Since we have no information about when adverse conditions were first encountered in the weather-related group we do not know whether or not the pilots deliberately continued their flights into marginal conditions or for how long. The findings are consistent with explanations based on proximity of the goal (i.e., the planned destination) and time already invested in the flight (sunk cost).

A cautionary note must be sounded in terms of the relatively small size of the sample available in the present study which means that the study may lack sufficient power to detect true differences between the sub-groups of crashes. It was extremely frustrating to find again and again that the database records kept by the official investigators were lacking basic details about the crashes. The reason for this is no doubt that busy investigators with high workloads find data-entry a low-priority task and so details which may subsequently be useful in an analysis such as this one are omitted to save time.

Given that the fundamental purpose of 'accident investigation' is the prevention of future accidents (8) a much higher priority ought to be placed on the recording of information from investigations for future analysis. This is particularly so for details which may seem to be quite irrelevant to the case at hand by the investigator. Such details may in fact turn out to be important when viewed from a certain distance. More importantly, such information can play a valuable role in providing 'control' information for comparison with a group of different events. An understanding of the importance of controls is part of basic scientific methodology which is not necessarily part of the current training of aircraft accident investigators (14).

It would certainly be desirable to replicate the present study with a much larger sample. Unfortunately NTSB records do not currently contain the information required for such an analysis. The relevant information on flight length and precise location of crash sites might however be found in databases elsewhere. Findings that the flight experiences of pilots in different countries are remarkably similar (12) supports the validity of generalizations from research in one country to another.

Whilst the injury outcomes of the two groups of crashes are significantly different there were very few differences between the two groups in terms of crash characteristics other than height of the crash site above sea level and reported visibility. The most striking difference was in terms of two characteristics of the pilots. Those involved in IFV crashes were much younger (by almost a decade) and had much higher flight hours in the previous 90 days. This combination of relative youth and high levels of current flight time has shown up repeatedly in the literature on pilot characteristics and flight safety as a risk factor for crash involvement (e.g., 3,11).

Within the IFV group, the ‘classic’ VFR into IMC crashes involved the youngest pilots and the highest number of hours in the previous 90 days. The basis for this group’s over-involvement in crashes cannot simply be their flight exposure as this would leave them equally at risk of other externally-driven ‘Act of God’ type of events. We hope that our concurrent program of laboratory-based research will provide additional information to identify the at-risk behaviors associated with this particular group of pilots. More research on this target group is clearly warranted.

Previous findings (13) have shown that pilots’ decisions in hypothetical scenarios can be altered by inducing them to ‘re-frame’ their investments in a flight in a positive (i.e., as gains) rather than a negative (i.e., time/money lost) fashion. Further educational efforts along these lines would seem to be warranted in view of the present findings that pilots involved in weather-related crashes have disproportionately greater investments in their flights than pilots involved in other types of crashes.

ACKNOWLEDGEMENTS

This research was supported by a Federal Aviation Administration Grant 00-G-009. The technical monitor was Dr David Hunter, Office of Aviation Medicine, FAA, Washington DC. We are grateful to the Civil Aviation Authority of New Zealand and the Transport Accident Investigation Commission of New Zealand for providing us with access to their accident databases. We are grateful to Adele Arnold for assistance with the distance formula.

Table 1. Mean and Median Values for Pilot and Contextual Factors by Types of Cross-Country Crashes

Type	#		Crash Distance from departure	Crash Distance as % of Overall	Height of Crash Site (AMSL)	Visibility	# Fatalities	Pilot Age (Years)	Pilot Hours (90 Days)
AOG	31	Mean	78.1	59.5	150		0.68	47.0	31.9
		SD	95.8	37.44	300		1.25	16.4	35.7
		Median	31.0	51.2	0	>20 km	0	45.5	22.0
IFV Total	46	Mean	72.9	65.2	2970		1.63	37.8	59.8
		SD	75.1	37.8	2203		2.51	11.9	59.4
		Median	44.0	61.3	2575	5 - 20 km	0.5	38.0	31.0
IFV - LOCA	14	Mean	49.7	46.8	1965		2.07	39.7	43.6
		SD	61.1	33.1	1631.3		2.7	13.1	53.1
		Median	26.9	38.7	2300	5 - 20 km	1.0	38.5	24.0
IFV – Weather (total)	28	Mean	92.5	77.9	3600		1.57	36.1	64.0
		SD	80.3	36.7	2700		2.56	11.6	64.5
		Median	66.3	80.4	2364.3	5 - 20 km	0	34.0	45.0
IFV - Weather (VFR/IMC only)	12	Mean	78.6	71.3	2200		1.75	32.4	74.7
		SD	60.6	30.6	745.6		2.26	9.83	71.7
		Median	53.1	85.0	2100	5 - 20 km	1.0	30.0	55.0
IFV - Weather (Other weather only)	7	Mean	60.7	95.8	5300		3.14	39.0	68.5
		SD	46.6	54.3	2552.6		3.72	13.52	61.4
		Median	43.8	85.1	5400	>20 km	1.0	39.5	58.0
IFV - Weather (Precautionary Landg only)	9	Mean	135.7	70.4	No Data		0.11	39.8	49.7
		SD	108.6	18.6			0.33	12.7	71.7
		Median	100.1	69.8		5 - 20 km	0	43.0	55.0

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Appendix 1

The Excel expression for the distance formula between points 1 and 2 is:

SQRT(POWER(60*(Lat 1-Lat 2),2)+POWER(60*(Lon 1-Lon 2)*(COS(Lat 1*PI()/180)+COS(Lat 2*PI()/180))/2,2))

Where Lat 1 and Lat 2 are the decimal values of the original (degrees/minutes) latitude coordinates and Lon 1 and Lon 2 are the decimal values of the original (degrees/minutes) longitude coordinates.