Civil Aeromedical Institute
Oklahoma City, Oklahoma

Pilot Age and Accident Rates: A Re-analysis of the 1999 *Chicago Tribune* Report and Discussion of Technical Considerations for Future Analyses

Dana Broach
FAA Civil Aeromedical Institute
Oklahoma City, Oklahoma 73125

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The Federal Aviation Regulations (FAR) (14 **CFR** § 121.383(c)) prohibits any air carrier from using the services of any person as a pilot, and prohibits any person from serving as a pilot, on an airplane engaged in operations under Part 121 of the FAR if that person has reached his or her 60th birthday:

> "*No certificate holder may use the services of any person as a pilot on an airplane engaged in operations under this part if that person has reached his 60th birthday. No person may serve as a pilot on an airplane engaged in operations under this part if that person has reached his 60th birthday.*"

The Federal Aviation Administration (FAA) adopted the "Age 60 Rule," as it has come to be known, in 1959 (24 **FR** 9767, December 5, 1959). However, it has been the subject of extensive debate and litigation (see General Accounting Office (1989) and Williams & Williams (1991) for reviews). Still, the FAA has concluded, after many scientific reviews and studies as well as public comments, that it could not be assured that raising the age 60 limit would maintain or raise the level of safety that the current rule provides.

Nevertheless, debate on the rule continues. For example, the *Chicago Tribune* (July 11, 1999) reported that older pilots were "…among the safest in the skies." The *Tribune* article was based on an analysis of data describing 450 accidents and incidents from FAA databases. The *Tribune* characterized the analysis as showing that incidents were "…spread fairly evenly across pilot age groups, when weighted in relationship to the number of pilots in each group." An outside expert reportedly characterized the differences in accident rates between pilots in different age groups as not statistically significant. The purpose of this study was to replicate the *Tribune* analysis as the second report of four studies to be conducted by the FAA in response to congressional concerns about the Age 60 rule.

Replication and Re-Analysis of the 1999 *Tribune* Study

The *Tribune* story indicated that data describing 450 "incidents" between January 1, 1990 and June 11, 1999 were obtained from the FAA under the Freedom of Information Act (FOIA). As described by the *Tribune*, most of the occurences "… involved things as minor as bumping into a baggage cart." However, the data also included 21 accidents that resulted in more than 700 deaths. The number of air carrier accidents for air transport pilots were tabulated by pilot age (Table 1) and then aggregated by 10-year age groups (20-29, 30-39, 40-49, and 50-59).

The next step was to estimate the accident/incident rates for each age group. The *Tribune*'s outside consultant estimated the accident/incident rate as the ratio of the number of occurences for the age group to the total number of Air Transport Pilots (ATPs) in the age group over the 9.5 years. To compute the denominator, the number of ATPs in each age group reported by the *Tribune* was multiplied by 9.5. The resulting rates for each group were then compared using a Z-test (Kanji, 1999, Test 5). The analysis is reproduced in Table 2.

Overall, there appeared to be no statistically significant differences in the accident/incident rates by age group. That is, as the *Tribune* reported, this analysis indicated that, for this data set, the proportion of older ATPs involved in an accident or incident was no greater than the proportion of younger pilots involved in an accident or incident.

A review of the *Tribune's* analysis indicated a simple arithmetical error in summing the number of accidents for the 40-49 age group. The number of accidents for that age group as used in the original *Tribune* analysis was 143, while the actual correct number of total accidents for the 40-49 age group was 156. The corrected analysis is presented in Table 3. The correction resulted in only small changes in the pattern of results. The accident/incident rates for 20-29, 30-39, and 40-49 year age groups were still not statistically different. However, the proportion of 50-59 year old ATPs involved in accidents or incidents was significantly lower than the proportion for the 40-49 year old group ($p_{(40\text{-}49)} = 0.00064$, $p_{(50\text{-}59)} = .00061$; $Z = -10.96$, $p = .000$).

An additional concern was the fact that the *Tribune* estimated the population of pilots by multiplying the number of ATPs in each age range by 9.5 (the number of years encompassed by the data set). While useful as a rough approximation of the ATP population, such an approach may over- or underestimate the actual number of pilots. Pilot census data are published by the FAA each year by type of pilot certificate (e.g., "license") and age. Therefore, we extracted ATP census data for each age range for the years 1990 through 1997 from the annual *U.S. Airmen Statistics* or the *FAA Statistical Handbook of Aviation*. The counts of ATPs by age group used by the *Tribune* were used for 1998 and divided by two, in keeping with the original methodology, to estimate the size of the 1998 and 1999 ATP population. The census counts by year and age group were summed across years to estimate the total population of ATPs by age group over the period of the study. Then, in keeping with the original *Tribune* methodology, the total number of accidents or incidents per age group was divided by the population of ATPs in that age group as estimated from the annual census reports. The subsequent analysis is presented in Table 4.

Overall, the original *Tribune* analysis underestimated the actual ATP population across the 9.5 years by almost 250,000 pilots. For example, the *Tribune* analysis estimated the population of 30-39 year old ATPs at 233,928 pilots, while FAA actual census figures indicate a total population of 322,296 in that age range across the 9.5 years. The population of 40-49 year old ATPs was similarly underestimated by the *Tribune* as 241,994 compared with a census count of 355,919. The 50-59 age group was also underestimated at 197,978, compared with a census count of 251,986.

However, the pattern of results based on the airmen's census is the same as reported in the original *Tribune* analysis. Specifically, the accident/incident rate decreased significantly between the 20-29 and 30-39 age groups ($p_{(20\text{-}29)} = .00070$, $p_{(30\text{-}39)} = .00037$, $Z = -2.87$, $p \leq .005$) and then appeared to stabilize. Older (50-59) pilots appeared to be at no greater statistical risk than pilots in the 40-49 age range.

The accident/incident rates by age group are illustrated in Figure 1. Three rates are graphed: (1) for the original *Tribune* analysis, (b) corrected accident count for the 40-49 year old age group, and (c) the corrected accident count for the 40-49 age group and the census counts of the ATP population for each age group. The three analyses show a decrease in the accident/incident rate between the 20-29 and 30-39 age groups, with the analysis based on census figures being statistically signficant. The accident probability then appears to stabilize across age ranges, with no statistical differences as age increases.

Technical Considerations for Future Analyses

While studies like the 1999 *Tribune* report and these re-analyses provide data for reasoned debate on the Age 60 Rule, they are by no means definitive. Further, more comprehensive investigations are warranted. There are important technical issues that must be carefully considered in order to conduct a more definitive, and informative, analysis with regard to Age 60. Federal aviation regulations such as the Age 60 rule are promulgated to minimize the risks associated with flying, that is, to ensure flight safety. Risk can be defined as the statistical probability that an event will occur within some period of time (Karvonen & Mikheev, 1986) and is frequently presented as a proportion or rate, computed as the ratio of occurences (the numerator) to some denominator representing the population at risk or degree of exposure to a hazard. Different units are used for the denominator, depending on the purpose of the analysis. Examples commonly used in aviation include the ratio of the number of accidents to the number of cycles of departures and landings (Boeing, 1997), the number of fatal accidents per 100,000 flight hours (FAA, 1999), and the number of accidents per 100,000 pilot flight hours (Golaszewski, 1983; Kay et al. 1994). The *Tribune* and other analyses illustrate the choices that must be made in estimating and comparing accident rates.

Li (1994) identified important methodological issues in epidemiologic studies of pilot-related factors such as age in aviation accidents and incidents. First, safety, as the objective risk of being involved in an accident, should be assessed relative to occurences and exposure to flight. Second, epidemiologic methods are particularly suited to such assessments. Third, widely accepted and standardized measures of risk and outcomes in aviation accident studies are not available. These methodological issues suggest that an assessment of aviation accidents and incidents in relation to exposure to flight and pilot age in a cross-sectional study design requires explicit choices about the numerator and denominator used to compute objective risks as well as the statistical methods used to analyze those risks.

Choices in Estimating the Numerator

Define the class of event to be counted. The first choice to be made is the definition of the events to be included in the numerator of an estimate of risk. For example, the *Tribune* report indicates that the numerator of the risk estimates included incidents ranging in severity from fatal to "bumping baggage carts." Accidents and incidents are more commonly analyzed separately, as they represent different classes of events that vary substantially in their severity (see Appendix A for regulatory definitions). An accident occurs when a fatality, serious injury, or substantial damage to an aircraft happens as the result of the operation of an aircraft. In contrast, an "incident" is defined as the occurrence other than an accident, associated with the operation of an aircraft, that affects or could affect the safety of operations.

Given the disparate nature of accidents and incidents, they will be analyzed separately by the Civil Aeromedical Institute in additional studies of accident/incident rates in relation to pilot age. Only those events classified by the NTSB as accidents will be counted in estimates of the numerator for accident rates. Similarly, only events classified as incidents in the FAA Accident/Incident Data System (AIDS) will be counted in estimates of the numerator for incident rates.

Number of events to be counted. The second choice to be made is identifying the population or sample of accidents and incidents to be used as the numerator in any estimate of risk. For example, the *Tribune* analysis reported 450 accidents and/or incidents for air carriers involving ATPs for the period January 1990 to June 11, 1999. The *Tribune* report did not specify the data source except as having been obtained under the Freedom of Information Act from the FAA. However, there are multiple sources for such data within the FAA, including the National Aviation Safety Data Analysis Center (NASDAC) and Flight Standards Regulatory Support Division. In addition, the NTSB is considered the official repository of aircraft accident data and causal factors.

For example, searching the NTSB Aviation Accident/Incident database via the publicly accessible NASDAC internet site (http://www.nasdac.faa.gov) for accidents involving scheduled Part 121 air carriers returned 282 reports for the period January 1, 1990, through June 11, 1999. A search for scheduled Part 121 air carrier incidents in the same NTSB database found 407 reports, for a total of 689 accidents/incidents for scheduled Part 121 operators covered by the Age 60 rule. A search of the FAA Accident/Incident Data System (AIDS) using the same parameters returned 4,353 reports of incidents for air carrier or commercial operators during the same time period. These differences suggest that counts of accidents and incidents may vary with the data source and the query parameters used to generate those counts. For example, the NTSB database differentiated specifically between (a) FAR operating authorities (Part 121 versus 135) and (b) scheduled versus non-scheduled operations. In contrast, the FAA/AIDS did not make distinctions within the rubric of "air carrier and commercial."

Therefore, additional studies of pilot age and accident/incident rates to be conducted by the Civil Aeromedical Institute will use accident and incidents that occurred in the course of Part 121 or 135 scheduled and unscheduled operations in the numerator. The data sources, query parameters, and search results used to generate the accident and incident data sets will be explicitly described. Missing data rates and the rules for inclusion or exclusion of records will also be disclosed. The goal is to ensure that planned analyses are credible, verifiable, and replicable.

Choices in Estimating the Denominator

Denominator unit. The third choice to be made in analyzing accident and incident risks in relation to pilot age concerns the unit for the denominator. The *Tribune* report used the number of pilots over the study period as the denominator for the risk estimate. In essence, the *Tribune* estimated the prevalence rate of accidents and incidents among ATPs for the period January 1, 1990 through June 11, 1999. The result was a person-based estimate of risk.

However, a person-based estimate of risk does not take into account the varying degrees of exposure to the hazards of flight between pilots. That is, some pilots fly more, some less. Given that there is no risk when not flying, the typical metric used to represent exposure to the hazards of flight is hours of flight time. For example, Golaszewski (1983, 1993) and Kay et. al (1994) used flight hours as a measure of exposure to the hazards of flight, expressed in units of 100,000 flight hours. To be consistent with previous research, 100,000 pilot flight hours will be used as the unit of the denominator for accident and incident rates in the additional studies of the Age 60 Rule.

Denominator population. The fourth choice to be made in the analyses of accident and incident rates in relation to pilot age is identifying the population or sample for which flight hours will be estimated. Various approaches have been used, including selecting the sample based on pilot certificate held, medical certificate class, and recent flight hours. However, the Senate report focused on "commercial pilots." Therefore, additional studies of pilot age and accident/incident rates conducted by the Civil Aeromedical Institute will define the general denominator population in terms of persons holding ATP and commercial pilot certificates (e.g., "licenses"), with Class II or Class II medical certificates, working for Part 121 or 135 certificated carriers with scheduled or unscheduled operations.

Data source. The fifth choice to be made in analyzing accident and incident rates in relation to pilot age is the data source for estimating the denominator in terms of flight hours. For example, the NTSB accident database includes estimates of flight hours in the last 24 hours and in the last 90 days prior to the accident. The database reports the total flight hours up to the accident for the pilot as well. The FAA AIDS includes similar data fields for incidents. However, an alternative source for estimating flight hours is the self-reported flight hours in the last year reported in the medical components of the Comprehensive Airmen's Information System (CAIS). The NTSB accident and FAA incident databases report flight hours only for pilots involved in an accident or incident. In contrast, the self-reported flight hours are available for all pilots through the medical component of the CAIS. The denominator must represent the degree of exposure for the population of pilots at risk (e.g., as defined above) in terms of flight hours, including those who have not been involved in an accident. Therefore, self-reported flight hours as reported in the medical component of the CAIS, will be used to estimate flight hours for the population at risk.

Statistical Choices

The final set of choices that must be made in analyses of accident and incident rates in relation to pilot age concerns the statistical methodologies to be used in making comparisons. For example, Golaszewski performed no formal statistical analyses in his initial 1983 report but incorporated such analyses in the 1993 report. In his 1993 study, Golaszewski analyzed the degree of association between age and accident rates using both Chi-square (χ^2) and regression analyses. In contrast, Kay et al. (1994) used an analysis of variance design and the *Tribune* used a Z-test of proportions to compare accident rates between age groups. These statistical techniques make specific assumptions about the nature and distribution of the accident data, flight hours, and computed rates. Kay and associates discussed some of these assumptions and their implications for the choice of statistical methods for analysis of accident rates by age. Other statistical methods, such as those used in epidemiologic research, might be useful in investigations of accident rates in relation to age. The technical considerations and issues associated with different statistical approaches are beyond the scope of this report, but it does highlight the need for expert consultation in the design and execution of the additional studies conducted by the Civil Aeromedical Institute on the relationship of accident and incident rates to pilot age.

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Appendix A

49 **CFR** 830.2 Definitions.
As used in this part the following words or phrases are defined as follows:

"Aircraft accident" means an occurrence associated with the operation of an aircraft which 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.

"Civil aircraft" means any aircraft other than a public aircraft.

"Fatal injury" means any injury which results in death within 30 days of the accident.

"Incident" means an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

"Operator" means any person who causes or authorizes the operation of an aircraft, such as the owner, lessee, or bailee of an aircraft.

Public aircraft means an aircraft used only for the United States Government, or an aircraft owned and operated (except for commercial purposes) or exclusively leased for at least 90 continuous days by a government other than the United States Government, including a State, the District of Columbia, a territory or possession of the United States, or a political subdivision of that government. "Public aircraft" does not include a government-owned aircraft transporting property for commercial purposes and does not include a government-owned aircraft transporting passengers other than: transporting (for other than commercial purposes) crewmembers or other persons aboard the aircraft whose presence is required to perform, or is associated with the performance of, a governmental function such as firefighting, search and rescue, law enforcement, aeronautical research, or biological or geological resource management; or transporting (for other than commercial purposes) persons aboard the aircraft if the aircraft is operated by the Armed Forces or an intelligence agency of the United States. Notwithstanding any limitation relating to use of the aircraft for commercial purposes, an aircraft shall be considered to be a public aircraft without regard to whether it is operated by a unit of government on behalf of another unit of government pursuant to a cost reimbursement agreement, if the unit of government on whose behalf the operation is conducted certifies to the Administrator of the Federal Aviation Administration that the operation was necessary to respond to a significant and imminent threat to life or property (including natural resources) and that no service by a private operator was reasonably available to meet the threat.

"Public aircraft" means an aircraft used exclusively in the service of any government or of any political subdivision thereof, including the government of any State, Territory, or possession of the United States, or the District of Columbia, but not including any government-owned aircraft engaged in carrying persons or property for commercial purposes. For purposes of this section, "used exclusively in the service of" means, for other than the Federal Government, an aircraft which is owned and operated by a government entity for other than commercial purposes or which is exclusively leased by such government entity for not less than 90 continuous days.

"Serious injury" means any injury which: (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second or third degree burns, or any burns affecting more than 5 percent of the body surface.

"Substantial damage" means damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component. Engine failure or damage limited to an engine if only one engine fails or is damaged, bent failings or cowling, dented skin, small punctured holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wingtips are not considered "substantial damage" for the purpose of this part.

Table 1.* *Chicago Tribune listing Air Carrier accidents involving ATPs by age for January 1, 1990 to June 11, 1999*

Pilot Age	Incidents/Accidents
No age listed	16
23	1
24	1
25	1
26	8
27	8
28	8
29	14
30	16
31	10
32	10
33	11
34	12
35	12
36	12
37	11
38	8
39	17
40	13
41	14
42	20
43	21
44	10
45	9
46	19
47	17
48	11
49	22
50	13
51	14
52	12
53	10
54	19
55	10
56	5
57	11
58	6
59	9
60	1
61	2
63	3
72	2
73	1
Total	450

Table 2.* *OriginalChicago Tribune Analysis*

	Age Group			
	20-29	30-39	40-49	50-59
N Accidents/incidents for age group	41	119	143	109
N Pilots in age group used by *Tribune*	5,846	24,624	25,473	18,945
Study length = 9.5 years	9.5	9.5	9.5	9.5
Total estimated pilots in age group over study period	55,537	233,928	241,993.5	179,977.5
Tribune p(accident/incident)	0.000738	0.000509	0.000591	0.000606
Difference in probabilities between age groups		-0.000230	0.000082	0.000015
Standard error for difference		0.000124	0.000068	0.000076
Z-test for difference		-1.85	1.21	0.19
Significance		0.0648	0.2261	.8469

Table 3.* *Chicago Tribune Analysis corrected for number of accidents in 40-49 age group*

	Age Group			
	20-29	30-39	40-49	50-59
N Accidents/Incidents for Age Group	41	119	156	109
N Pilots in Age Group @ Jun 1999	5,846	24,624	25,473	18,945
Study length = 9.5 years	9.5	9.5	9.5	9.5
Total estimated pilots in age group over study period	55,537	233,928	241,993.5	179,977.5
corrected *p*(accident) (1)	0.00074	0.00051	0.00064	0.00061
Difference in probabilities between age groups		0.00023	-0.00014	0.00004
Standard error for difference		0.00012	0.00007	0.00005
Z-test for difference		1.85	1.95	10.96
Significance		0.06485	0.05060	0.00000

Table 4.* *Tribune analysis recomputed on airman's census data*

	Age Group			
	20-29	30-39	40-49	50-59
N Accidents/Incidents for Age Group	41	119	156	109
N Pilots in Age Group @ Jun 1999	5846	24624	25473	18945
Study length = 9.5 years	9.5	9.5	9.5	9.5
Total estimated pilots in age group over study period	58,869	322,296	355,919	251,986
corrected *p*(accident) (2)	0.00070	0.00037	0.00044	0.00043
Difference in probabilities between age groups		0.00033	-0.00007	0.00001
Standard error for difference		0.00011	0.00005	0.00005
Z-test for difference		2.87	-1.42	0.11
Significance		0.00406	0.15646	0.91581

*Note: Tables 1-4 reflect different Ns for accidents/incidents for age groups. Table 1 (N=450) sums all of the accidents listed by the *Chicago Tribune* for the reporting period. Table 2 (N=412) does not include 25 accidents/incidents because the age of the airmen involved was not reported for 16 cases and, in 9 other cases, the airmen was over age 60; additionaly, Table 2 reflects an error in the *Chicago Tribune's* reporting 143 accidents/incidents for the 40-49 age group, when the acctual number was 156. Tables 3 and 4 (N=425) use the number of accidents/incidents of which theairmen's age was reported and where that age was under 60, and the correct number (156) of accidents/incidents for the age group 40-49is used in both of those tables.

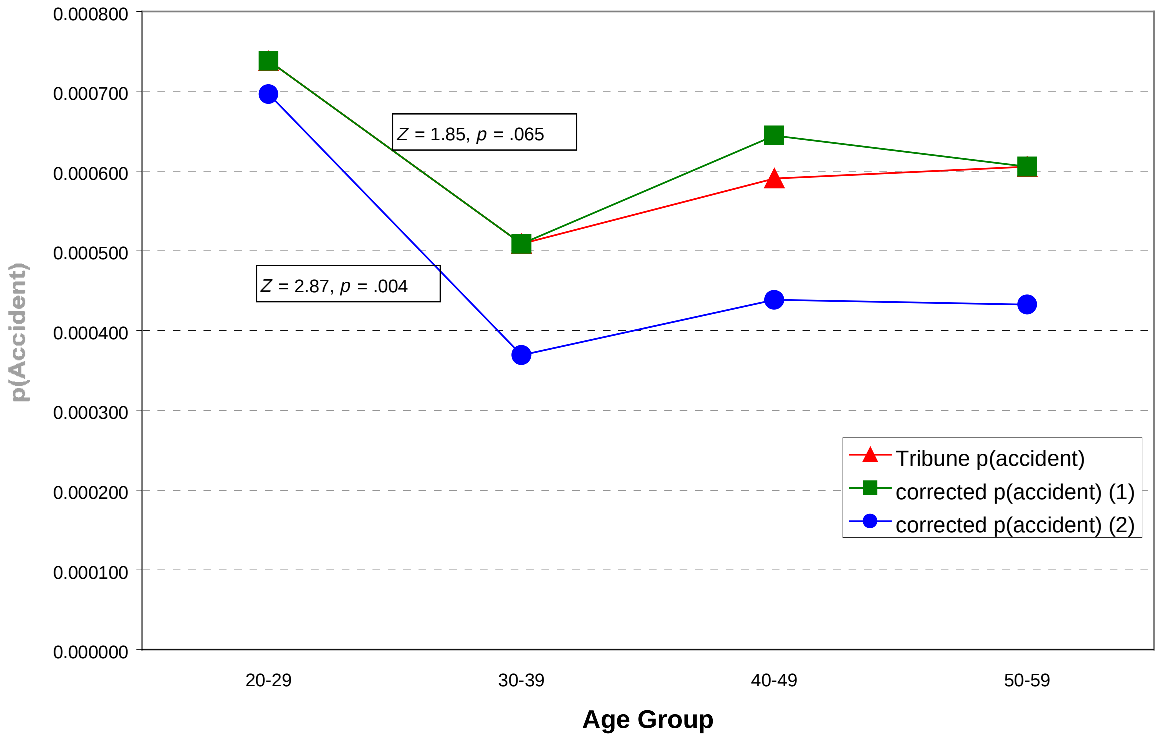

Figure 1. *Comparison of original Tribune results to (1) results corrected for accident count in 40-49 age group, and (2) actual historical ATP census data*