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Crash Rates of Scheduled Commuter and Air Carrier Flights Before and After a Regulatory Change

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Abstract

Introduction—In 1997, in an effort to reduce the crash rate of scheduled commuter flights, the FAA required aircraft with 10–30 passenger seats to operate under stricter rules. Training and other requirements of 14 CFR Part 121 rules were applied to these midsize commuters, which previously had operated under the less strict Part 135 rules. Published crash rates obscured changes related to aircraft size. This research was undertaken to determine whether the rule change affected crash rates of aircraft with 10–30 passenger seats.

Method—We determined the number of passenger seats on each Part 135 or Part 121 aircraft that crashed between 1983 and 2007. For aircraft with < 10, 10–30, and > 30 seats, we estimated the numbers of departures and crash rates, adjusting for changes in total departures and numbers of in-service aircraft.

Results—The Part 135 crash rate tripled in 1997 when commuters with 10–30 seats were excluded, reflecting the administrative change. However, the crash rate of aircraft with 10–30 passenger seats began to decline 4 yr before the rule change; thereafter, their rate was lower than for larger aircraft. The fleet size of aircraft with 10–30 passenger seats increased from 1983 to 1997, then declined as they were replaced with larger aircraft in response to the rule change.

Discussion—No effect of the rule change on crash rates of 10–30-seat aircraft was apparent. The decline in their crash rates began before the rule change and may have been related to the 1992 requirement for ground proximity warning devices.

Keywords

passenger seats; aircraft size; regulation change

Throughout the period 1977–1994, scheduled commuter flights had far higher crash rates than major airlines (3,8,9). The safety record of commuter aircraft has long been of concern (11). In the early 1990s, Baker and colleagues described the circumstances of commuter crashes during 1983–88 and suggested that commuter flights should be subject to some of the stricter

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safety standards that protect passengers flying on Part 121 airlines (1,2). In 1994, the National Transportation Safety Board (NTSB) published the findings of a study of commuter airline safety and recommended that the FAA revise its regulations so that the provisions of Part 121 would be applied to all scheduled service in aircraft with 20 or more passenger seats and, wherever feasible, to aircraft with 10–19 seats (12). The NTSB based its recommendations on findings regarding Part 135 practices, including the following: flight time and crew rest regulations had resulted in many commuter pilots flying when fatigued; the short periods of time between flights increased the risk that pilots would make critical mistakes in planning for the next flight; many airlines failed to provide adequate training in crew resource management; and newly trained pilots might not be adequately trained.

For decades, scheduled flights of aircraft with > 30 passenger seats have been subject to Part 121 regulations. In 1995 the FAA published new requirements for commuter operations (7) in response to the high crash rates of Part 135 flights and the NTSB recommendations (12), as well as to several highly publicized fatal crashes of commuters with 10–30 seats in 1993–94 (10). The new rule stated that after March 20, 1997, all scheduled flights of aircraft with 10–30 passenger seats would be required to operate under Part 121 rules (7) (aircraft with 10–30 passenger seats are primarily turboprops, unlike the larger turbojet aircraft that have always been subject to Part 121 rules).

A decade of data on flight operations and crashes since 1997 is now available, but has not been used to evaluate the effect of the rule change. A major reason for failure to examine the trend is that the FAA and NTSB categorize and publish the numbers of scheduled flight departures and crashes not by aircraft size but by whether they are governed by Part 135 or Part 121 rules. Prior to 1997, published data on departures and crashes of Part 135 flights combined aircraft having 10–30 passenger seats with aircraft having < 10 passenger seats; after 1997, crashes and departures of aircraft with 10–30 seats could not be separated from crashes and departures of aircraft with more than 30 passenger seats because they were combined in Part 121 data.

Whether there was any change in crash rates of aircraft with 10–30 seats—the operations that were the focus of the rule change—could not be determined from the published data. This paper determines and reports crash rates of three categories of scheduled aircraft flights—those with < 10, 10–30, and > 30 passenger seats—before and after the rule change. Our primary objective was to identify any apparent effect of the regulatory change on aircraft with 10–30 seats, since these flights were specifically targeted by the FAA rule change. Additional objectives were to determine trends in crash rates of all scheduled flights, categorized by size—i.e., the number of passenger seats.

METHODS

Crash rates for each year were based upon the number of crashes in relation to the number of departures. Departures are a better measure of exposure than the number of aircraft miles or flight hours because short flights entail greater exposure per mile or per hour to the hazards associated with takeoffs and landings and flight at low altitude. Published data were obtained on the numbers of crashes and departures of scheduled Part 135 and Part 121 flights during 1988–2007 (10) and comparable data for 1983–1987 were provided by NTSB. To determine whether the 1997 rule had an apparent effect on the overall crash rate of scheduled flights, data for crashes and departures of Parts 135 and 121 flights were combined and overall rates calculated.

After March 20, 1997, following the transfer to Part 121 jurisdiction of flights with 10–30 seats, all scheduled Part 135 flights were of small aircraft with fewer than 10 passenger seats; therefore, scheduled Part 135 published data for that period were specific to flights with < 10

seats. Similarly, published rates for Part 121 crashes prior to 1997 were specific to flights with > 30 passenger seats, which were the only flights subject to Part 121 regulations at that time. After March 20, 1997, however, Part 121 data did not separate aircraft with 10–30 seats (previously operated under Part 135) from larger aircraft traditionally covered by Part 121, and before that date the Part 135 data did not separate aircraft with 10–30 seats from those with < 10 seats. Therefore, it was necessary to develop a method to estimate the number of departures by aircraft size during both periods.

In order to categorize aircraft in crashes by the number of seats, data were obtained from the NTSB accident data system on the total number of seats in each aircraft that crashed during 1983–2007 while flying under scheduled Part 135 or 121 rules. For any crash where the record did not specify the number of seats, the number was determined by matching that aircraft with other aircraft of the same type having a known number of seats. Thus it was possible to categorize all crashes by whether the number of passenger seats was < 10, 10–30, or > 30, the three relevant categories (if the total number of seats in an aircraft was between 11 and 33, the number of passenger seats was 10–30, the remaining 1 to 3 being crew seats).

Between 1996 and 1998, there was a jump in Part 121 departures and a drop in Part 135 departures, reflecting the transfer of aircraft with 10–30 seats to Part 121 in 1997 (Table I). Departures in 1998 were compared with departures in 1996: there were 2.7 million more Part 121 departures and 2.8 million fewer Part 135 departures (a difference of only 4%). The annual number of departures of scheduled flights with 10–30 seats in 1996–98 was, therefore, considered to be the median of these two figures, 2.75 million. The proportion of departures associated with 10–30-seat aircraft during 1983–1996 was first calculated to be 78% of scheduled Part 135 flights, based upon 2.75 million flights divided by 3.52 million (the total number of scheduled Part 135 departures in 1996), and the proportion with < 10 seats was calculated to be 22%, the difference between 100% and 78%. Subsequently, the number of departures was adjusted based upon changes in the number of aircraft in service with 10–30 passenger seats. Similarly, the proportion of departures of flights with 10–30 passenger seats in 1998 was calculated to be 26% [2.75 million flights divided by 10.54 million (the total number of Part 121 departures in 1998)], with the remaining 74% of Part 121 departures in that year assumed to have > 30 seats.

To measure changes in the use of 10–30-seat aircraft during the study period, the number of the 4 most common aircraft (EMB-120, DHC-6, BE-1900, and Fairchild Swearingen Metro) being flown with 10–30 passenger seats was ascertained. According to aircraft usage data compiled and reported by insurance providers, there was a 47% reduction between 1997 and 2007 in the number of these 4 aircraft in service, from 675 on January 1, 1997, to 356 on January 1, 2007 (Table II). This change in the fleet size, based on the reported numbers of the 4 most common in-service aircraft with 10–30 passenger seats, was used to adjust the denominator, taking into account the steeper decline after 2002. For the years 1999–2007, the estimated number of departures (Table I) reflected this 47% reduction in fleet size of 10–30-seat airplanes. Between 1983 and 1997 the size of the fleet of 10–30-seat aircraft more than doubled (Table II). The numbers of departures in these years were adjusted to reflect this in a manner corresponding to the post-1997 adjustment.

For aircraft with > 30 seats, the number of departures after 1997 was determined by subtracting the departures of aircraft with 10–30 seats from the published total number of Part 121 departures. Departures prior to 1997 of aircraft with < 10 seats were determined by subtracting the departures of aircraft with 10–30 seats from the published total number of Part 135 departures. Departures and rates in 1997 were excluded from the above analysis because the regulation took effect part way through 1997. All rates reported in this paper are for scheduled flights. Pearson's Chi-square test was used to test for significant differences. The study was

exempt from institutional review; it did not involve identifiable human subjects and was based upon publicly available data.

RESULTS

Part 135 vs. Part 121 Crash Rates

Prior to 1997, when all scheduled aircraft with < 30 passenger seats flew under Part 135 regulations, the Part 135 crash rate decreased gradually from 6.9 per million departures in 1983 to 3.1 in 1996 ($P = 0.0002$) (Fig. 1). The Part 135 rate jumped to 11.3 in 1998 after aircraft with 10–30 seats were moved to Part 121, then declined to 5.3 per million departures in 2007 ($P = 0.07$). The crash rate of Part 121 flights climbed in 1995, increased again in 1997 when flights with 10–30 seats were first included, and remained high through 2003 before declining to an all-time low of 2.1 in 2004 (Fig. 1). For the 5-yr period 2003–07, the crash rate for Part 135 was more than twice the rate for Part 121, 6.5 vs. 3.0 per million departures ($P = 0.001$). The crash rate for all scheduled flights (Parts 135 and 121 combined) closely followed the rate for Part 121, which included the great majority of scheduled operations. For all scheduled operations, the overall crash rate was higher from 1997 to 2003 than for 1990–96 (Fig. 1).

Crash Rates by Number-of-Seats Category

10–30 seats—From 1983 through 1992, commuters with 10–30 passenger seats had substantially higher crash rates than larger aircraft (Table I). A decrease in the number and rate of crashes of aircraft with 10–30 seats began 4 yr prior to the 1997 rule change; for the 4 yr 1993–1996, the average rates were 2.0 and 3.2 per million departures for 10–30-seat and > 30-seat aircraft, respectively ($P < 0.0001$). The crash rate for 10–30-seat commuters was the same in 1998–2002 (after the rule change) as in 1993–96, 2.0 per million departures. For the 5-yr period 2003–07, the crash rates were 6.5 per million departures for flights with < 10 seats, 1.6 for 10–30 seats, and 3.2 for > 30 seats ($P = 0.0003$).

< 10 seats—After the rule change, the rate of crashes of aircraft with < 10 passenger seats initially quadrupled, returning to the pre-1994 level (Table I, Fig. 2). From 2003–2007, however, the rate was much lower, averaging 6.5 per million departures, less than half the rate of 15.4 per million departures for the prior 5 yr, 1998–2002 ($P = 0.001$). The crash rate of this smallest group of commuters was consistently higher than the rates for midsize and larger airplanes (Fig. 2).

> 30 seats—Large airplanes experienced a higher-than-previous crash rate during 1998–2002 (Table I, Fig. 2). This was followed by lower rates during 2003–2007 ($P = 0.006$), similar to the rates for 1983–87.

DISCUSSION

The 1997 rule change, published in 1995, was designed to improve the safety of middle-sized aircraft (10–30 passenger seats) by placing them under the stricter Part 121 regulations governing larger aircraft. Published FAA data and Fig. 1 showed increases in the rates of Part 135 and Part 121 crashes after 1997, but did not reveal whether there had been any change in the safety of scheduled flights with 10–30 seats, the subject of the 1997 rule change. Results of these analyses illustrate the big difference between published rates based upon the applicable regulatory Part and rates based upon the number of passenger seats. Since the regulations differentiate on the basis of number of seats, the latter calculations are necessary to discern any actual effect of a rule change that was based upon passenger seats.

The 1997 regulatory change expanded the applicability of Part 121 regulations to include scheduled passenger operations involving medium-sized (10–30 passenger seat) “commuter” aircraft, previously governed by scheduled Part 135 regulations. The immediate effects on published crash rates were a sudden tripling of the Part 135 rate (in part because of shifting safer operations to Part 121) and a slight increase in Part 121 rates (which now included a group of operations with higher rates than traditional Part 121 operations). Overall, the rate for all scheduled operations combined also increased. Only by distinguishing among aircraft of various sizes, however, was it possible to examine trends in crash rates of aircraft with 10–30 seats.

When scheduled flights were categorized by the number of passenger seats rather than by FAA operational requirements (Part 135 vs. Part 121), it became evident that beginning in 1994—3 yr before the rule took effect—crash rates of flights with 10–30 seats (the subject of the 1997 rule change) were even lower than crash rates of flights with more than 30 seats. Nor did these midsize commuters experience a change in crash rates after 1997: their average crash rate for the first 5 yr after the rule change was the same as for the 4 yr prior to the change. Crash rates of all three sizes of aircraft were lower in 2003–07 than in 1998–2002; the 10–30-seat commuters showed the least change between these two periods.

Reasons for the improved safety prior to 1997 of scheduled commuters with 10–30 seats probably include the 1992 requirement that all turbine-powered aircraft with 10 or more seats must be equipped with approved ground proximity warning systems to prevent their all-too-prevalent controlled-flight-into-terrain crashes (13). Subsequent to 1997, the rule’s requirements for improved training may have contributed to these midsize commuters maintaining a low crash rate. Although other aspects of the rule may also have contributed, the initial intent to impose stricter requirements for flight and duty time has never been implemented (14).

The reduction in scheduled Part 135 crash rates both before and after the rule change is in contrast to the lack of a consistent reduction in mishap rates of Part 121 flights, which did not change markedly during 1983–2003 (4,10) [we generally use the term ‘mishap’ rather than ‘crash’ in connection with Part 121 because a large proportion of Part 121 adverse events are injuries resulting from turbulence, rather than crashes (4)]. Other research, however, has shown that certain types of Part 121 mishaps did change in their incidence rates: in particular, the rates of mishaps on the ground increased, especially those in the ramp area or while taxiing (2).

After 2000, crash rates of scheduled Part 135 operations involving the smallest scheduled aircraft—those with < 10 passenger seats—declined dramatically (Table I, Fig. 2). This decline was not a result of the rule change, which did not affect the smaller aircraft now comprising all of the Part 135 operations. Post-1997 rates for these smallest commuters are actual (not estimated) because the numbers of both crashes and departures were known. Since 1997, 91% of these small-commuter crashes have occurred in Alaska, where major efforts have been made recently to reduce crashes. Among such efforts by the FAA is the Alaska Capstone project, which provides pilots with information on weather, terrain, and air traffic and permits trained pilots to fly safely at lower altitudes using GPS (6). An additional measure was the installation of live remote cameras in mountain pass locations to provide weather information (5). The very high crash rates of scheduled commuters, which prior to 1997 combined small with midsize (10–30-seat) commuters, may have contributed to the FAA decision to subject midsize commuters to Part 121 regulations.

Limitations of this study include the small numbers of crashes, which make the changes in trends unstable. To counteract this problem, data for 5-yr periods were combined. Another limitation is the need to estimate the frequency of departures in relation to the number of seats,

which was accomplished by applying percentages based upon changes in the fleet of in-service aircraft with 10–30 seats, and changes in the number of departures in 1998 vs. 1996, which presumably represented departures of 10–30-seat commuters. Estimates further from 1997—in the 1980s, for example—may be less valid than those closer to 1997.

As illustrated in Table II, the fleet size of 10–30-seat commuters changed considerably during the study period. Prior to 1997, commuter service using this size of aircraft was increasing. The decline in the number of in-service aircraft with 10–30 seats after the rule change is worthy of note because it reflects airline decisions to operate with larger aircraft once the incentive of less-strict Part 135 regulations was no longer pertinent. Researchers should be alert for this type of phenomenon, which may influence the effect of other regulatory changes.

The practice of combining published crash rates of scheduled commuters having 10–30 seats with the very high rates of commuters with < 10 seats contributed to the appearance that these midsize aircraft had high crash rates prior to the regulatory change that took effect in 1997. The major strength of the study is the use of data on the number of passenger seats to divide the aircraft into three meaningful categories based on the number of seats, thereby making it feasible to evaluate the possible safety effect of a rule that otherwise could not be analyzed.

A major implication of this research is that the safety of Part 135 commuters (i.e., the smallest commuters) deserves continued attention. The recent attention to air safety in Alaska is promising. For all three size categories of scheduled flights, the downward trend in recent years is encouraging. While the trend may not specifically reflect changes due to the 1997 rule change, the continued attention to aviation safety by the NTSB, the FAA, and the aviation community appears to be bearing fruit.

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Fig. 1. Crashes per million departures of scheduled flights, Part 135 and Part 121, 1983–2007.

Fig. 2.

Crashes per million departures of scheduled flights by number of seats, 1983–2007.

TABLE I
Departures And Crashes, 1983–2007, By Number Of Passenger Seats In Part 135 And Part 121 Scheduled Aircraft.

Year	Part 135 Departures (millions)		Part 121 Departures (millions)		Departures (in millions)			Crashes			Crashes/Million Departures		
	Part 135 Departures (millions)	Part 121 Departures (millions)	< 10 seats	> 30	< 10	10–30	> 30	< 10	10–30	> 30	< 10	10–30	> 30
1983	2.33	5.24	1.09*	5.24	1.24*	5.24	5.24	5	9	22	4.6*	7.3*	4.2
1984	2.68	5.67	1.35*	5.67	1.32*	5.67	5.67	9	10	13	6.7*	7.6*	2.3
1985	2.56	6.07	1.14*	6.07	1.42*	6.07	6.07	10	8	17	8.7*	5.6*	2.8
1986	2.80	6.93	1.28*	6.93	1.52*	6.93	6.93	3	9	21	2.3*	5.9*	3.0
1987	2.81	7.29	1.19*	7.29	1.62*	7.29	7.29	14	17	32	11.8*	10.5*	4.4
1988	2.91	7.35	1.11*	7.35	1.80*	7.35	7.35	6	12	27	5.4*	6.7*	3.7
1989	2.82	7.27	0.83*	7.27	1.99*	7.27	7.27	8	12	20	9.6*	6.0*	2.8
1990	3.16	7.80	0.96*	7.80	2.20*	7.80	7.80	7	8	19	7.3*	3.6*	2.4
1991	2.82	7.50	0.39*	7.50	2.43*	7.50	7.50	10	11	21	25.5*	4.5*	2.8
1992	3.11	7.52	0.43*	7.52	2.68*	7.52	7.52	11	11	15	25.6*	4.1*	2.0
1993	3.60	7.72	0.90*	7.72	2.70*	7.72	7.72	9	7	22	10.0*	2.6*	2.8
1994	3.58	7.82	0.87*	7.82	2.72*	7.82	7.82	5	5	18	5.8*	1.8*	2.3
1995	3.22	8.11	0.49*	8.11	2.73*	8.11	8.11	7	4	30	14.3*	1.5*	3.7
1996	3.52	7.85	0.77*	7.85	2.75*	7.85	7.85	2	6	31	2.6*	2.2*	3.9
1997**													
1998	0.71	10.54	0.71	10.54	2.75*	7.79*	7.79*	8	3	38	11.3	1.1*	4.9*
1999	0.67	10.86	0.67	10.86	2.53*	8.33*	8.33*	13	3	37	19.3	1.2*	4.4*
2000	0.60	11.05	0.60	11.05	2.33*	8.72*	8.72*	12	8	41	19.9	3.4*	4.7*
2001	0.56	10.63	0.56	10.63	2.15*	8.48*	8.48*	7	6	35	12.5	2.8*	4.1*
2002	0.51	10.28	0.51	10.28	1.98*	8.29*	8.29*	7	4	30	13.6	2.0*	3.6*
2003	0.57	10.23	0.57	10.23	1.86*	8.37*	8.37*	2	5	46	3.5	2.7*	5.5*
2004	0.54	10.78	0.54	10.78	1.75*	9.04*	9.04*	4	4	19	7.4	2.3*	2.1*

Year	Part 135 Departures (millions)	Part 121 Departures (millions)	Departures (in millions)			Crashes			Crashes/Million Departures		
			< 10 seats	10–30	> 30	< 10	10–30	> 30	< 10	10–30	> 30
2005	0.53	10.91	0.53	1.64*	9.27*	6	3	30	11.4	1.8*	3.2*
2006	0.57	10.63	0.57	1.54*	9.09*	3	0	26	5.3	0.0	2.9*
2007	0.57	10.72	0.57	1.45*	9.27*	3	1	23	5.3	0.7*	2.5*

* Estimates based upon NTSB data and published tables (10) plus: a. assumption that the change between 1996 and 1998 in the number of Part 135 and Part 121 departures reflected the number of departures of aircraft with 10–30 seats; b. 47% decrease between 1997 and 2007 in the proportion of aircraft in service with 10–30 seats; and c. 122% increase between 1983 and 1997 in the proportion of aircraft in service with 10–30 seats.

** Departures in 1997 were excluded from the analysis because the regulation took effect part way through 1997.

Trends In Numbers Of Aircraft With 10–30 Passenger Seats, U.S. Commercial Passenger Operations With Reported Status Of “In Service” 1983–2007.

TABLE II

Aircraft with 10–30 Passenger Seats	As of 1/1/1983	As of 1/1/1987	As of 1/1/1992	As of 1/1/1997	As of 1/1/2002	As of 1/1/2007
EMB-120	0 (orders only)	17	170	232	161	90
BE-1900	0 (orders only)	62	182	281	206	164
DHC-6	135	84	82	68	60	56
Metro *	169	236	226	94	60	46
TOTAL	304	399	660	675	487	356

Source: Ascend Online Fleets, Ascend Worldwide Ltd., <http://www.ascendworldwide.com/>.

* Fairchild Swearingen Metro.