Analysis of Airline and Aircraft Safety Posture Using Service Difficulty Reports

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The objective of this paper is to analyze an important aspect of the safety posture of airlines during the years following deregulation using service difficulty reports (SDRs). Safety posture is measured by the incidence of serious aircraft service difficulties that can be taken as an indication of the potential for safety failures. SDRs report aircraft problems encountered while in operation. They vary in severity from the mundane to the serious. Despite the weaknesses stemming from potentially poor reporting, SDRs can be taken as one indicator of the effectiveness of an airline's maintenance program and can therefore shed some light on safety posture. In explaining safety posture, variables used are an airline's maintenance expenditures, aircraft fleet composition and age, and scale of operation. We also differentiate between carriers established before airline deregulation and new entrants. With the help of statistical analysis on data for the period 1980–1984, we look at some of the evidence on airline safety posture as defined. The consistent evidence we have suggests that safety posture, as indicated by SDRs, is associated with the scale of operations—the rate of serious SDRs per block hour is likely to increase with exposure (stage length) and decrease with the number of departures. The rate of serious SDRs per departure is likely to decrease with number of block hours of operations. The aging of aircraft, with respect to SDRs, is significantly different for different aircraft size groups—large wide-bodied aircraft appear to have a sharper increase in the incidence of SDRs with age than do the smaller narrow-bodied aircraft. Further, there is also consistent evidence that the incidence of SDRs is not any higher for the new entrants than it is for the established carriers.

Airline safety has always received a substantial amount of attention from the aviation industry, policy makers, and the general public. Concern has increased in the years following deregulation of the airlines, and safety has become an important topic in public debate and mass media coverage. One of the key issues being discussed is whether there has been a deterioration of safety since airline deregulation.

The Airline Deregulation Act of 1978 has resulted in a highly competitive environment and has also permitted the entry of many new airline firms into the industry. One of the primary concerns has been that these new firms might not be able to operate as safely as the more experienced ones. One of the main reasons for this concern is that perhaps the new entrants would be more strapped financially and would therefore adopt cost-cutting strategies at the expense of safety. The main objective of this paper is to analyze one important indicator of the safety posture of airlines with specific attention to new entrants.

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Safety Posture

It is fortunate that aircraft accidents and incidents are rare. Nonetheless, accidents, fatalities, and their rates have traditionally been used to analyze safety performance in civil aviation. As Figure 1 shows, the rate of incidents of these rare events have declined precipitously since the mid-1950s. This rarity of events complicates statistical analysis and leaves one searching for elusive causal relationships. If the proposition is accepted that an aircraft or an airline that experiences a high incidence of mechanical difficulties in service may be *positioned* with a higher risk of accidents or incidents, then the concept of safety posture can be used as a possible indicator of an airline's risk and consequently of safety. But it is rather hard to test this proposition because there are not enough accidents to yield significant evidence. The analysis of safety posture can have important implications for the development of preventive safety programs such as maintenance or inspection.

Safety posture is measured by the incidence of service difficulties. These are difficulties encountered while an aircraft is in service and usually refer to mechanical problems. They are recorded in service difficulty reports (SDR) that are assembled by the FAA. SDRs are classified into five severity groups ranging from minor, nonthreatening service difficulties such as the failure of galley equipment to serious service difficulties that are often life threatening such as in-flight engine failure. As indicators of safety posture, all SDRs could be examined or only the serious ones. In this study, SDRs with the highest two severity levels are classified as "serious" for two reasons:

- Serious and total SDRs are correlated.
- Serious SDRs are likely to be reported vigilantly.

There are difficulties involved in using SDRs as numeric indicators. One major difficulty is the reporting issue. FAA

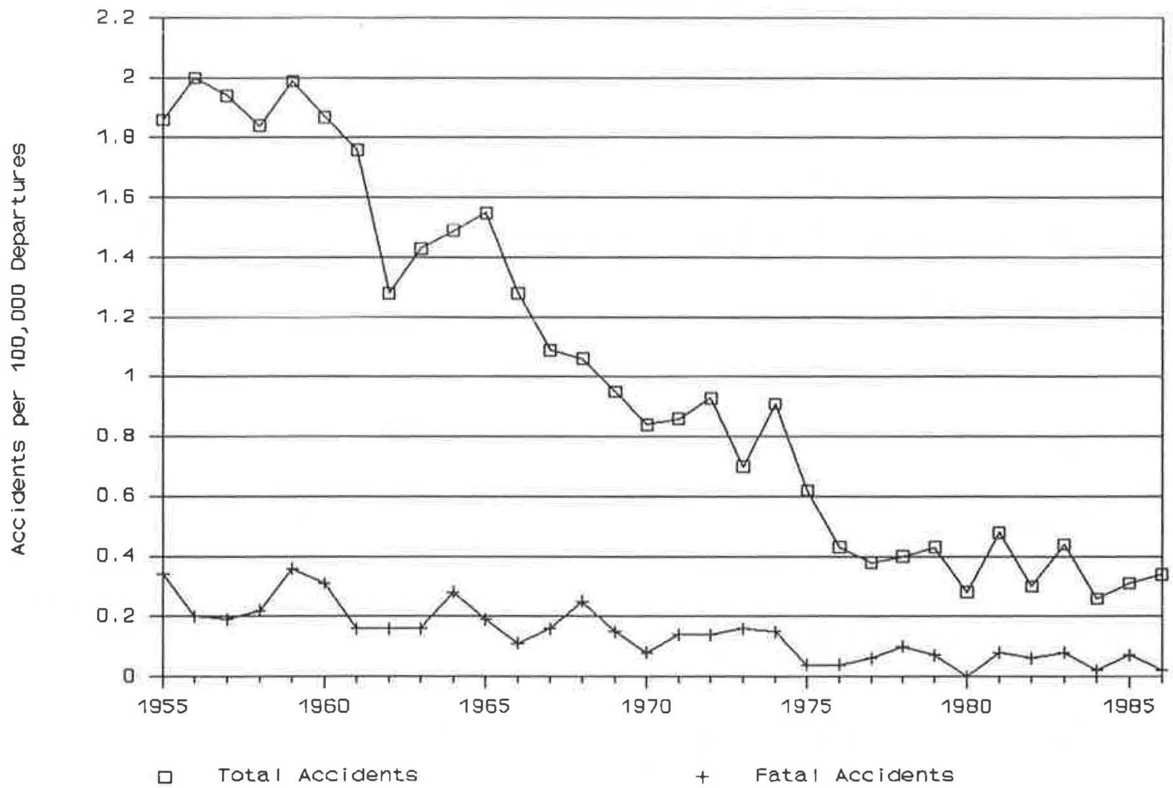

FIGURE 1 Accident rates of U.S. certificated air carriers.

regulations require that service difficulties be reported, however, little is done to ensure compliance. Little is known about the incidence of noncompliance but the general suspicion is that reporting is inadequate (*1*). In using serious SDRs only, and in staying with comparative analysis, the impact of poor data reporting should be minimized. Another difficulty with SDRs is the apparent ambiguity in the causal relationship between maintenance and the detection of service difficulties. When aircraft maintenance and inspection is vigilant, detection and reporting of service difficulties is more likely. If this is true, then the higher incidence of SDRs may be representing a higher level of vigilance and consequently a better safety posture. To prove this assumption would require an in-depth analysis of the relationship between SDRs and maintenance expenditures and procedures. Such an analysis is outside the scope of this study but has been reported elsewhere (*2*). Research suggests that the relationship between maintenance expenditures and SDR rates is elusive, and that other indicators of maintenance practice need to be analyzed. In this study, the focus on serious SDRs is also an attempt to get at an indication of safety posture that transcends this possible ambiguity. It is hard to believe that a higher incidence of serious, life-threatening SDRs does not reflect a deteriorating safety posture, regardless of the maintenance practices.

Previous work is reviewed, factors believed to affect air carrier safety posture are discussed, and results of the statistical analysis of the SDRs are presented. To analyze safety posture, propositions are made about the following factors in the causal chain:

- Aircraft fleet composition and age,
- Scale of operation and route network characteristics, and
- Airline operating structure and size.

PREVIOUS WORK

A debate has been sparked regarding the expected safety of the airline system after deregulation. The economic competition introduced by deregulation has forced the industry to increase productivity and efficiency. Increased productivity and efficiency have resulted in pressures to reduce operating costs. Maintenance, which is a substantial proportion of an airline's operating costs, may be jeopardized in some airline's cost cutting efforts. In an era of intense competition, new carriers could have a weaker financial posture than established carriers. It has been argued that this represents added pressure to take cost-saving shortcuts on maintenance.

On the other hand, as Kanafani and Keeler (*3*) point out, the new entrants should have a strong incentive to maintain good records to build a safety reputation. A serious accident is likely to be more detrimental to the reputation of a new carrier than to an established carrier. Consequently, new entrants can be expected to devote more of their resources to safety.

Although there are two sides to the argument regarding the expected safety posture of new entrants, very little empirical evidence has been produced. Work that sheds indirect light on the argument deals with the relationship between safety performance and financial health of an airline. Graham and Bowes (*4*) investigate the link between a firm's financial condition and its accident rates, maintenance expenditures, and service complaints. The relationship between profitability and accidents is analyzed by Golbe (*5*) who shows that the financial strength of a carrier does not have an effect on its propensity for accidents. Rose (*6*) investigates the relationship between accident rates and financial performance of air carriers, and finds that on an aggregate level, lower operating profit margins do not imply higher accident rates. Oster and Zorn (*7*) find that the new commuter air carriers have slightly higher accident rates in that category.

However, these studies address only the accident rates rather than safety posture. Advanced Technology (*8*) analyzes the bivariate correlations between financial measures and a carrier's inspection ratings in the FAA's National Air Transportation Inspection (NATI) program of 1984 and finds a clear correlation between financial posture and safety posture. Kanafani and Keeler (*3*) find essentially no difference between the safety records of new entrants and established carriers using accident rates, near mid-air collisions (NMACs), NATI performance, and maintenance expenditures. Recent research on SDRs, reveals economies of scale of operations associated with safety posture, making the larger carriers *appear* better positioned in terms of safety, but the *actual* posture of new carriers may be better than that of the established carriers.

INFLUENCES ON AIRCRAFT SAFETY POSTURE

Aircraft safety ultimately depends on aircraft maintainance. An airline's maintenance activities and expenditures are dependent on many important factors such as age and composition of the aircraft fleet, scale of operations, and operating structure and size. All of these factors influence an airline's maintenance policy, its level of maintenance expenditures, and potentially its safety posture. This study postulates some relationship between these factors and the incidence and severity of SDRs. Using a data base for 1980–1984, these postulates are tested statistically.

It is expected that older aircraft would require a greater level of maintenance activity as various components age. To corroborate this empirically requires care in evaluating maintenance expenditures. As aircraft age and amortize, an airline is less likely to pay for nonessential maintenance such as seats, walls, and so forth. Therefore, the statistics might show a reduction of maintenance expenditures with age for some aircraft types. It is also expected that older aircraft would experience a higher rate of SDRs than newer aircraft of the same type. A question to be resolved empirically is whether this is always the case or whether maintenance expenditures do neutralize the effect of age. The composition of a carrier's aircraft fleet is another factor that could influence its maintenance activity and SDR performance. This study explores how different aircraft types, and maintainenance expenditures for each type, affect the results.

In order to account for any possible economies of scale involved with the maintenance activity, the scale of operations is considered. Scale effect can stem from the exposure of aircraft that fly longer hours or engage in more frequent operations. Also, scale effect can stem from the size of an airline's flight operations or maintenance program. The number of departures and the number of flight hours are appropriate indicators of the scale of operations of the specific aircraft type. The average stage length tells something about the route network of the carrier, and it is inversely proportional to departures for a given number of flight hours. For any given aircraft type, these output indicators reflect the effect of exposure, but another measure is needed to account for the size of the airline itself. An airline structure indicator, in the form of an overall airline size stratifier, is postulated. Finally, to permit comparison among airlines and aircraft types, SDR rates based on departures and flight hours are studied.

The incidence of SDRs varies widely among aircraft types and airlines. Some of these variations are shown in Figure 2 for the DC-9 and in Figure 3 for the B-747 aircraft. The wide-bodied B-747 aircraft report a significantly higher rate of SDRs than the narrow-bodied DC-9 aircraft. These figures also suggest that the relationship between aircraft age the incidence of SDRs is not clear, implying that age alone does not have a specific influence on the incidence of SDRs. The effect of age is probably compounded with the effect of other factors. As is discussed later, the results of the statistical analysis suggest age as a significant factor, but show that other factors and interactions are also important.

DATA, ANALYSIS AND RESULTS

The SDR data are compiled by the FAA. The analysis period, namely 1980–1984, was chosen to examine a period sufficiently close to the start of deregulation in 1978, yet far enough away to provide some time for the carriers to make adjustments to their new operating environment and for some new carriers to establish themselves in the market. The latest year for which complete data were available at the start of this research was 1984.

The data on flight hours and average stage length are as reported in the *Aircraft Operating Cost and Performance Report* published by the U.S. Department of Transportation (DOT). The number of departures is derived by using average airborne speed, average stage length, and number of airborne hours of operations. The financial data on maintenance expenditures are also obtained from the same source. The aircraft fleet age data were obtained from the *Inventory and Age of Aircraft: Majors and Short-Haul Nationals* published by the Civil Aeronautics Board. Additional information on aircraft fleet composition and age was obtained from the Avmark Database. The pooled cross section and time series data set, with one observation per aircraft type per carrier per year, contains 274 observations.

The data include the "majors" and the "nationals" of the U.S. air carriers operating during 1980–1984. The Hawaiian and Alaskan carriers were not included in the data panel because of the significant difference in their operating environment. The classification of the carriers as new entrants follows Kanafani and Keeler (*3*). As justified there, Continental and Braniff are classified as new entrants following their reorganizations; Pacific Southwest Airlines is classified as an established carrier and Southwest Airlines is classified as a new entrant.

The airlines are also stratified into five groups (Table 1) based on their size and organizational structure. Group 1 is made up of the largest airlines, and the inclusion of Eastern Airlines in Group 2 was intended to keep the Texas Air group together, although they were not consolidated during the study

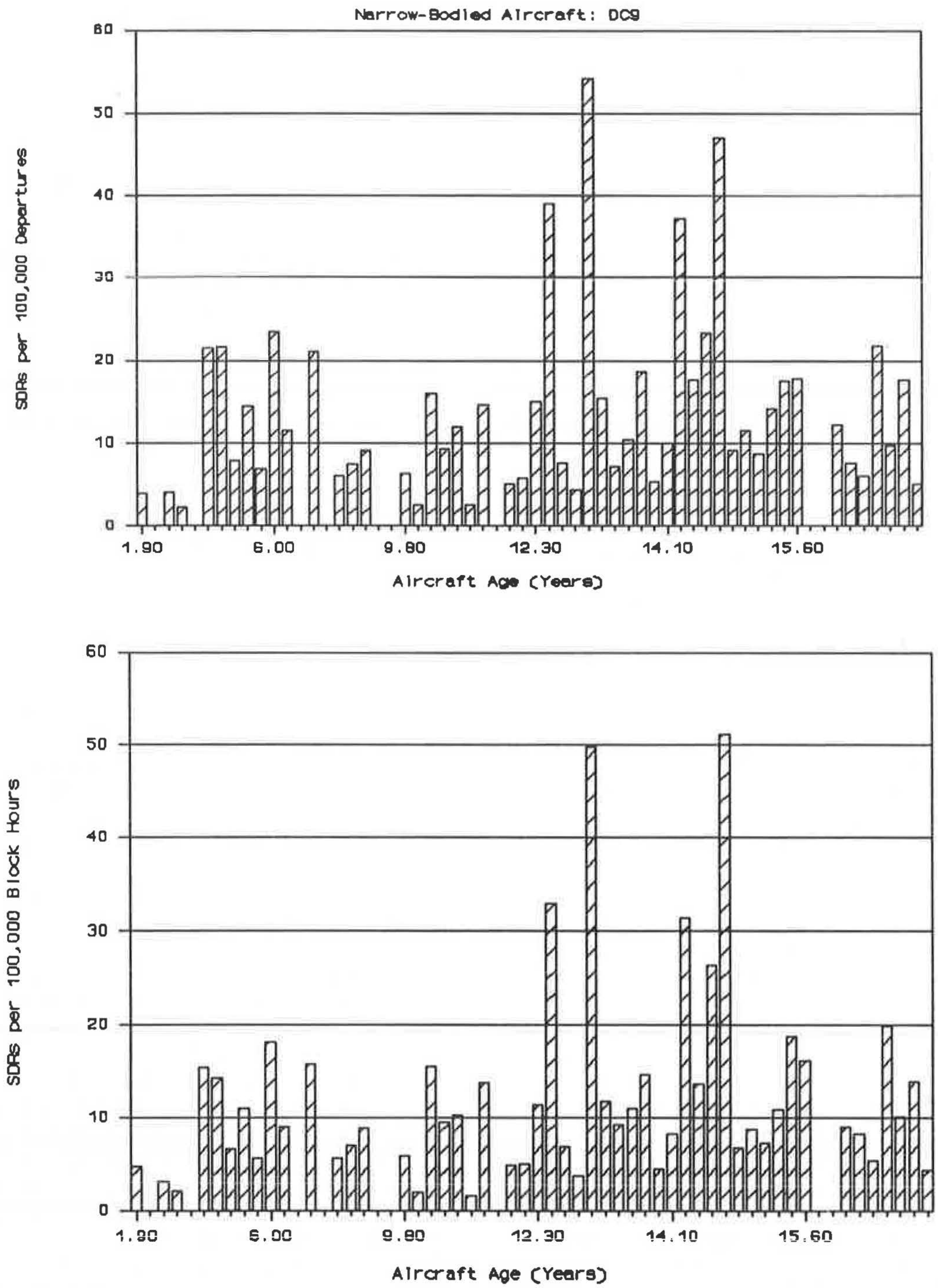

FIGURE 2 Rate of serious SDRs versus aircraft age for narrow-bodied aircraft (DC-9).

period. Similarly, the airlines comprising the current USAir group have been lumped together in Group 3. As a result, Northwest Airlines falls in Group 4 even though it would have been in a group with larger carriers had the classification been based solely on size. Group 5 is made up of airlines that are more regional in nature. There is a certain degree of arbitrariness involved in the study's classification scheme.

Variations of the same aircraft model are combined to form one aircraft group. For example, DC-10-10, DC-10-30, DC-10-40—which are all variations of the DC-10 aircraft model—are put together in the aircraft group DC-10. This resulted in seven different aircraft groups in the data set: B-727-100, B-727-200, B-737-200, B-747, DC-9, DC-10, and MD-80. The B-757 and B-767 aircraft have not been included in the analysis because they had just been introduced to the air transportation industry.

The variation of age, maintenance expenditure per block hour, stage length, and rate of serious SDRs for the seven

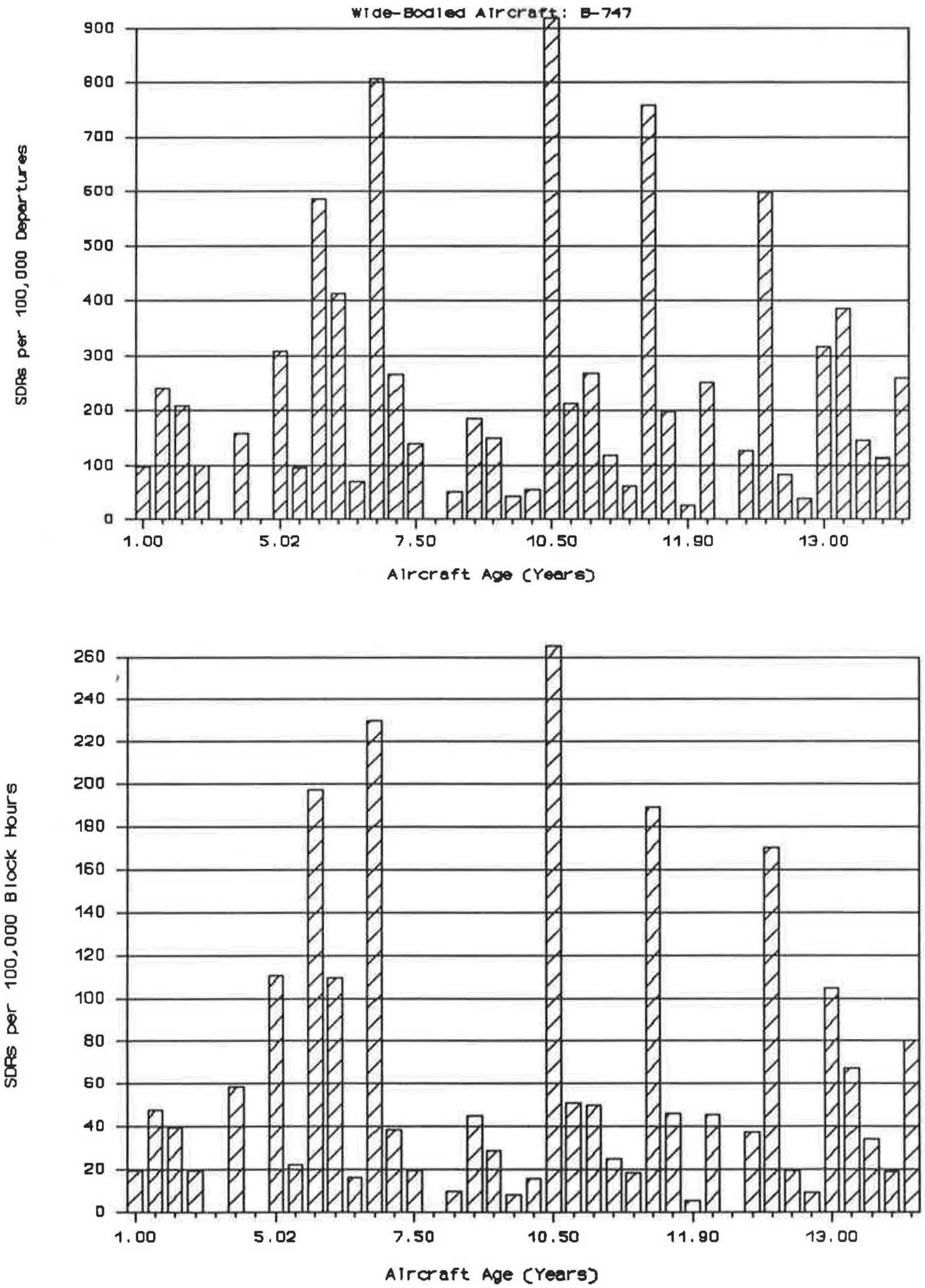

FIGURE 3 Rate of serious SDRs versus aircraft age for wide-bodied aircraft (B-747).

groups of aircraft are given in Table 2. These are the average values for the entire data set from 1980 to 1984. It can be observed from the table that large wide-bodied aircraft such as the B-747 and the DC-10 appear to have significantly different operating characteristics compared with the other types of aircraft. These wide-bodied aircraft have longer lengths of haul, higher rates of serious SDRs, and greater maintenance expenditures per block hour. Further, the SDR rate per departure for these wide-bodied aircraft are much higher than the SDR rate per block hour when compared with the other aircraft groups. This could be the result of the higher number of block hours per departure (the longer stage lengths for these aircraft), suggesting the presence of some nonlinear "exposure" factor related to flight hours. This analysis uses the rate of serious SDRs per 100,000 block hours as well the serious SDR rate per 100,000 departures. The variables are

TABLE 1 AIRLINE GROUPS BY SIZE AND ORGANIZATION

Group 1	Group 2	Group 3	Group 4	Group 5
American	Continental	Piedmont	Northwest	Aircal
Delta	Eastern	PSA	Ozark	Air Florida
TWA	Texas Int'l	USA	Republic	Frontier
United	Panam	Western	Southwest	
	Braniff			

two different rates of serious SDRs. The variables discussed in the previous section are to be used as explanatory variables.

The SDR models are then specified in multiplicative form to allow for interaction among factors as follows:

$$(SDR/Blkhr) = e^{a0} * NEWENT^{a1} * \mathrm{DEPS}^{a2} * STGL^{a3} * AG7271^{a4} * AG7272^{a5} * AG7371^{a6} * AG747^{a7} * AGDC10^{a8} * AGDC9^{a9} * GROUP1^{a10} * GROUP2^{a11} * GROUP3^{a12} * GROUP4^{a13}$$

A logarithmic transformation is then applied to permit simple statistical estimations:

$$\mathrm{Ln}(SDR/Blkhr) = a_0 + a_1\,\mathrm{Ln}(NEWENT) + a_2\,\mathrm{Ln}(DEPS) + a_3\,\mathrm{Ln}(STGL) + a_4\mathrm{Ln}(AG7271) + a_5\,\mathrm{Ln}(AG7272) + a_6\,\mathrm{Ln}(AG7371) + a_7\,\mathrm{Ln}(AG747) + a_8\,\mathrm{Ln}(AGDC10) + a_9\,\mathrm{Ln}(AGDC9) + a_{10}\,\mathrm{Ln}(GROUP1) + a_{11}\,\mathrm{Ln}(GROUP2) + a_{12}\,\mathrm{Ln}(GROUP3) + a_{13}\,\mathrm{Ln}(GROUP4)$$

where

SDR/Blkhr = serious SDRs per 100,000 block hours,
SDR/Dep = serious SDRs per 100,000 departures,
NEWENT = (e^0,e^1) dummy variable for new entrants,
DEPS = number of departures (in 1,000s),
BLKHRS = number of block hours (in 1,000s),
STGL = average stage length (in miles),
AGxxxx = average age of aircraft group "xxxx" (in years), and
GROUPy = airline Group "y"—(e^0,e^1) dummy variable.

This specification is to estimate the serious SDR rate per 100,000 block hours. Similarly, in the mode for the serious SDR rate per 100,000 departures the independent variable for the block hours is to be used in place of the variable for the number of departures.

The *AGxxxx* variables are defined as

$$AGxxxx = AGE \text{ if Aircraft Group} = \text{xxxx}$$
$$= e^0 = 1 \text{ otherwise.}$$

This enables the capture of the interaction of the age of the aircraft groups with the rate of SDRs. An identical approach is adopted for defining the *GROUPy* variables also. In addi-

TABLE 2 AIRCRAFT OPERATING CHARACTERISTICS: SDR ANALYSIS: 1980–1984

Aircraft Group	Age Years	Maint. Exp. $/BkHr	Stage Length Miles	Deps 1000's	Block Hours 1000's	SDRs/100,000 BlkHrs	SDRs/100,000 Deps
B-727-100	16.00	117.02	580	29.9	51.9	14.41	20.15
B-727-200	7.02	87.70	620	81.9	137.7	13.37	20.46
B-737-200	7.77	99.68	354	85.0	93.5	16.09	17.92
B-747	9.09	305.20	2056	4.2	18.9	63.89	267.51
DC-9	11.47	95.53	374	86.6	99.0	11.11	12.64
DC-10	7.69	233.04	1449	19.2	60.8	14.72	49.60
MD-80	0.88	48.88	605	20.4	30.1	14.37	21.34

tion, the logarithmic transformation of the rates of SDRs are modified and computed as follows:

$$SDR/Blkhr = SDR/[(BLKHRS * 1{,}000)/100{,}000]$$

$$SDR/Dep = SDR/[(DEPS * 1{,}000)/100{,}000]$$

and

$$\text{Ln}\ (SDR/Blkhr) = \text{Ln}\ [\{(SDR/Blkhr) + 2\}]$$

$$\text{Ln}\ (SDR/Dep) = \text{Ln}\ [\{(SDR/Dep) + 2\}]$$

This is equivalent to increasing the SDR rate by two uniformly across the data set. This has been adopted to ensure that there would be no negative values for the SDR rates after the logarithmic transformation and is necessary because the actual SDR rate is less than unity for some observations.

To analyze safety posture, a total of eight alternative specifications—four for the SDR rate per block hour and four for the SDR rate per departure—are presented. In the first model, the rate of SDRs are explained by using *NEWENT*, *DEPS*, and *AGxxxx* as explanatory variables. The *NEWENT* variable allows us to measure whether new entrants have a safety posture that is significantly different from the established airlines as evidenced by the SDRs. Accordingly, the variable *NEWENT* takes on a value equal to e^1 for the new entrant airlines and e^0 otherwise.

In the second model, *GROUPy* variables are included to observe the variation of the SDRs with the size and organization of the airlines. The *STGL* variable is introduced in the third specification wherever the *GROUPy* variables are dropped from the second model, in order to determine the influence of stage length on the rate of SDRs. Finally, the fourth model includes all the explanatory variables used in the first three models.

The results of the analysis for the SDRs per block hour are given in Table 3 and those for the SDRs per departure are given in Table 4. They are notable on several counts. First, the coefficients of the dummy variable for new entrants are consistently negative and are always significant. This suggests that the safety posture of the new entrants is, if anything, better than that of the established carriers. Second, the coefficients of departures and block hours in the respective models are always negative and very significant. When specified in conjunction with the stage length variable, the variable for departures is probably capturing the scale effects in the models for SDRs per block hour while the stage length accounts for the exposure effect. Thus, air carriers with a greater number of departures of a particular aircraft are likely to have a lower than average "rate" of serious SDRs. Because stage length is an inverse measure of exposure in this case, the negative sign of its coefficient is to be expected. Stage length does not appear to be significant in the model for SDR per departure probably because departures have already been normalized. If any, the coefficient of stage length is expected to have a positive sign because for a given number of departures, the number of hours per flight and a direct relation to stage length, is a measure of the exposure. So the negative sign of the coefficient in the third model is contrary to the study's expectations, whereas in the fourth model the coefficient of stage length is not significant, which is what was expected.

TABLE 3 SUMMARY OF SDR/BLKHR ANALYSIS

Independent Variable	Dependent Variable: SDR/Blkhr Estimates of the Coefficients for Model 1	Model 2	Model 3	Model 4
Constant	2.941	2.924	10.355	8.763
	12.56	*10.38*	*8.32*	*5.70*
NEWENT	-0.376	-0.350	-0.302	-0.357
	-2.35	*-1.95*	*-2.00*	*-2.04*
DEPS	-0.211	-0.146	-0.287	-0.238
	-3.53	*-2.42*	*-4.99*	*-3.75*
STGL	- -	- -	-1.134	-0.892
			-6.05	*-3.86*
AG7271	-0.040	0.038	-0.043	-0.011
	-0.50	*0.46*	*-0.57*	*-0.13*
AG7272	0.187	0.254	0.266	0.276
	1.67	*2.20*	*2.51*	*2.45*
AG7372	0.311	0.281	0.113	0.143
	2.66	*2.47*	*0.99*	*1.23*
AG747	0.418	0.615	0.943	0.925
	4.11	*5.74*	*7.31*	*7.02*
AGDC10	0.101	0.261	0.525	0.513
	0.96	*2.36*	*4.32*	*4.07*
AGDC9	0.125	0.170	-0.034	0.024
	1.33	*1.72*	*-0.37*	*0.23*
GROUP1	- -	-0.710	- -	-0.333
		-2.85		*-1.27*
GROUP2	- -	-0.449	- -	-0.152
		-1.74		*-0.58*
GROUP3	- -	0.244	- -	0.164
		0.92		*0.63*
GROUP4	- -	-0.356	- -	-0.234
		-1.43		*-0.96*
R-Square	0.265	0.333	0.354	0.369
Adj. R-Sq.	*0.243*	*0.302*	*0.332*	*0.338*
F-Statistic	12.0	10.9	16.2	11.8
Deg. of Freedom	266	262	265	261

NOTE: The *t*-statistics are presented below the coefficients.

Third, the variables used to account for the age of the different aircraft types present an interesting picture. From our attempts to arrive at a proper model specification, age and aircraft types were both observed to be very significant factors influencing the rate of SDRs. The interaction terms for the age of the aircraft groups were introduced in order to capture the aging process of the different aircraft groups. The coefficients of the variables representing B-747, DC-10, and B-727-200 are always positive and very significant. Among these three aircraft groups, the coefficients decrease in their order of magnitude and also in their level of significance in the order B-747, DC-10, and B-727-200. Note that this order suggests that the larger wide-bodied aircraft experience a greater-than-average increase of their SDR rates as they age.

TABLE 4 SUMMARY OF SDR/DEP ANALYSIS

Independent Variable	Dependent Variable: SDR/Dep Estimates of the Coefficients for Model 1	Model 2	Model 3	Model 4
Constant	3.581 *12.87*	3.478 *10.20*	6.337 *4.66*	5.026 *3.05*
NEWENT	-0.392 *-2.27*	-0.417 *-2.06*	-0.345 *-1.99*	-0.414 *-2.05*
BLKHRS	-0.284 *-4.27*	-0.218 *-3.00*	-0.281 *-4.26*	-0.230 *-3.12*
STGL	- -	- -	-0.433 *-2.07*	-0.240 *-0.96*
AG7271	-0.046 *-0.52*	-0.009 *-0.10*	-0.056 *-0.64*	-0.027 *-0.28*
AG7272	0.296 *2.24*	0.308 *2.20*	0.297 *2.44*	0.302 *2.33*
AG7372	0.224 *1.82*	0.197 *1.59*	0.122 *0.93*	0.148 *1.11*
AG747	0.937 *8.90*	1.042 *9.03*	1.153 *7.79*	1.136 *7.50*
AGDC10	0.479 *4.06*	0.554 *4.41*	0.636 *4.55*	0.623 *4.30*
AGDC9	0.052 *0.52*	0.071 *0.66*	-0.031 *-0.30*	0.020 *0.17*
GROUP1	- -	-0.432 *-1.53*	- -	-0.330 *-1.10*
GROUP2	- -	-0.214 *-0.74*	- -	-0.126 *-0.42*
GROUP3	- -	0.179 *0.60*	- -	0.161 *0.54*
GROUP4	- -	-0.274 *-0.99*	- -	-0.237 *-0.84*
R-Square	0.485	0.500	0.493	0.502
Adj. R-Sq.	*0.470*	*0.478*	*0.476*	*0.477*
F-Statistic	31.3	21.9	28.7	20.3
Deg. of Freedom	266	262	265	261

NOTE: The *t*-statistics are presented below the coefficients.

This may be because these aircraft have three or four engines and that many of the serious SDRs related to the maintenance of engines. The larger aircraft appear to have a faster aging process than the smaller ones, at least as far as safety posture and serious SDRs are concerned.

Fourth, the variables for the size and organizational characteristics of the airlines only result in a marginal improvement of the explanatory power of the models. The airlines represented by *GROUP1*, the largest four, are consistently better than the rest of the airlines although the coefficients are not very significant. Also, the *GROUP3* airlines are consistently worse, and once again the coefficients are not very significant. This suggests that there are differences between the airlines. This relates to the structure of the organization of each airline and its management. It is difficult to quantify this aspect of airline operation and, consequently, it is difficult to capture all the differences between airlines in the models. Perhaps, difference in safety performance among airlines should be explained by researching the underlying differences in organizational and management structure. Quantitative empirical work of the type presented here is unlikely to shed much light on these differences, although it does certainly point to their existence and significance.

Fifth, the analysis explains the rate of SDRs per departure better than the rate of SDRs per block hour as can be seen from the R^2 values. Maintenance problems related to fatigue of the airframe and aircraft components depend more on the number of cycles of operations performed than on the number of hours of operation. On the other hand, corrosion problems relate more directly to the age of the aircraft and environmental conditions. Perhaps it is the number of cycles of operation that is more significant for aircraft maintenance. This analysis suggests that SDR per departure may be a better measure of the safety posture from a maintenance point of view.

The coefficients of determination, R^2, varies from 0.27 to 0.50 and the F-statistics indicate significant results. Thus, the underlying factors that appear to be influencing airline safety posture can be explained in part.

An unexpected result is that the inclusion of maintenance expenditures in the models does not improve the explanatory power. Maintenance expenditure was seen to be strongly correlated to the rate of SDRs, but there appears to be other exogenous forces involved in the causal link between maintenance expenditures and the rate of SDRs. The exact nature of the causal relationship is not clear—is the maintenance expenditure dependant on the SDRs or are the SDRs dependant on the maintenance expenditure? Using the maintenance expenditure that is lagged over a time period may help shed more light on the nature of the causality of the relationship between these variables. Another factor that might be important is the utilization rate of aircraft and equipment.

The airlines have been classified into groups with a certain degree of arbitrariness. Techniques such as factor analysis may be useful in arriving at a classification that is more rational and meaningful. These are areas of further research that are suggested from this analysis.

CONCLUSIONS

The consistent evidence from this study suggests that there are some scale economies in favor of safety posture, as indicated by the SDRs. The evidence suggests that the rate of serious SDRs per block hour is likely to increase with exposure (stage length) and decrease with the number of departures. The rate of serious SDRs per departure is likely to decrease with number of block hours of operations. Another important piece of evidence is that the increased incidence of SDRs with age is significantly different among the different aircraft types. In general, large wide-bodied aircraft appear to have less tolerance to age than smaller aircraft.

Further, there is no evidence that the safety posture of new entrants is any better or worse than that of the established carriers. This can be taken to mean that if deregulation has increased the entry of new air carriers into the air transportation market, then by doing so it has not adversely influenced aircraft safety. On the contrary, one might go as far as inferring from these results that the smaller aircraft typically operated by new entrants are, if anything, safer than the rest of the fleet. However, given the difficulties of the data base that were discussed earlier in this paper, a strong statement cannot be made one way or the other. Besides, the analysis does not consider other factors such as airspace congestion that may have been affected and that may have a relation to safety.

The factors included in this analysis are by no means exhaustive and there remain a number of factors and issues to be studied more closely. Some of these are network characteristics, aircraft and equipment utilization rates, and airline organizational structure and management practices. Quantification of the organizational structure and management of the airlines poses problems, but there is some indication that these may be particularly important factors influencing the safety posture.

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