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Aviation Safety Priorities in Emerging Air Transport Systems

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This paper describes a meta-analysis of aviation safety summaries. The intent is to demonstrate that domestic aviation safety priorities have been influenced by summaries and analyses of worldwide aviation accident data. This paper further demonstrates that priorities in aviation safety may change when the parameters of an analysis vary by technologic, geographic, or regulatory attributes. This paper also discusses the validity of transferring priorities in aviation safety across industry segments (delineated by these same attributes), each of which may have unique hazard and vulnerability exposures. Collectively, this paper discusses the potential for identified aviation safety priorities (which may be biased toward dominant industry segments) to mask unique hazard and vulnerability exposures inherent in emerging aviation markets. This potential biasing of safety priorities becomes a more critical topic when viewed from the perspective of a future commercial aviation industry with a greater reliance on Part 135 commuter- and air-taxi-type operations using nontowered airports under a high-volume operations paradigm.

I. Introduction

THIS paper has two purposes. The first is to demonstrate that priorities in aviation safety can be biased toward specific industry segments that may not be fully representative of other subsets of aviation. The second is to demonstrate that establishing safety priorities based on worldwide operations or specific segments of aviation may not be directly applicable to all subsets that cross regional (national or continental), regulatory (Code of Federal Regulations, or CFR, Title 14 Parts 121 and 135), or technological (jet, turboprop, large aircraft, small aircraft, etc.) boundaries. Specifically, this paper demonstrates that safety priorities in domestic commercial aviation operations have been biased to reflect the accident profile of international commercial operations. A meta-analysis of published safety summaries is used to demonstrate the limitations of any assumption that an accident profile of some subset within a global aviation market is correlated to global aviation in the aggregate. The authors consider this review of real vs perceived domestic commercial aviation safety priorities to be a critical factor in forming the perspective that emerging and nascent aircraft operations and aviation markets, such as high-volume operations (HVO) at nontowered airports and the burgeoning air-taxi industry using light and very light jets (VLJ), may have unique hazard and vulnerability exposures relative to more traditional commercial aviation markets. If these emerging industry sectors are not critically analyzed for sector-specific hazards and vulnerabilities, there is a potential for increased numbers and rates of accidents as these sectors grow. Any such increase could lead to subsequent delays in societal acceptance of HVO in the nontowered "community" airport environments and potential delays in the growth of these emerging aviation markets that would directly affect the capacity of the commercial air transport industry in the aggregate as the hub-and-spoke infrastructure nears its maximum capacity.

This paper first revisits an earlier work by the authors [1] that critically reviewed aviation accident data summaries compiled and released by various governmental, nongovernmental, and quasi-governmental organizations [2–6]. In this previous work, the authors made three observations about common methods of accident data aggregation:

1) Summaries that aggregate worldwide accident data depict the current state of safety for civil commercial air transport as a model of some global norm of operations.
2) Segments of the worldwide aviation industry that contribute nontrivially to the fatal accident data record were masked from specific analysis due to the method and level of data aggregation.
3) Accident data of industry segments masked from specific analysis correlate with emerging markets in domestic operations (such as Part 135 commuter and air-taxi operations).

The potential implications of these observations are threefold:

1) Using summary data of a broad worldwide industry spectrum of operations can bias perceived safety priorities toward the perspective of a summary's producer.
2) Biased safety priorities are not necessarily directly transferable between a global norm of operations and location-specific industry segments.
3) Trends in accident occurrence that are driven by location-specific factors (including regulatory and operations oversight) may be underrepresented or misrepresented in a greater global data set.

Two examples follow. The first notes the limitations of aggregating diverse classes of aircraft that contribute to worldwide aviation accidents in a single summary. The second outlines the limitations in extending the global analysis to geographically defined regions.

Through 2005, the Boeing Airplane Company and the International Civil Aviation Organization (ICAO) used different accident classification taxonomies. Boeing used 17 accident classifications in its annual summary of worldwide fatal and hull loss accidents [2]. The ICAO Accident/Incident Reporting (ADREP) Circular summary used seven [3]. The data from these two summaries are jointly plotted in Fig. 1 using the histogram of the Boeing summary. The Boeing summary is specific to jet aircraft of over 27,000 kg maximum takeoff mass (MTOM) in commercial operations [2]. The ICAO circular incorporated a broader spectrum of aircraft, including jet aircraft over 5700 kg MTOM and turboprop and piston driven aircraft over 5700 kg MTOM [3]. As can be seen in Fig. 1, the ICAO and Boeing summaries indicate similar percentages of controlled flight into terrain (CFIT) and loss of control in-flight (LOC-Flight) (60 and 49%, respectively). Beyond these categories, the two summaries deviate with respect to accident profiles. For example, the Boeing summary indicates 15% of fatal accidents occur during the landing phase of flight [2]. The ICAO summary depicts landing accidents as trending toward zero [3]. Such a dichotomy dictates that the ICAO taxonomy is more loosely defined, ultimately allowing a greater aggregation of underlying data. One potential outcome of the ICAO summary incorporating geographically and

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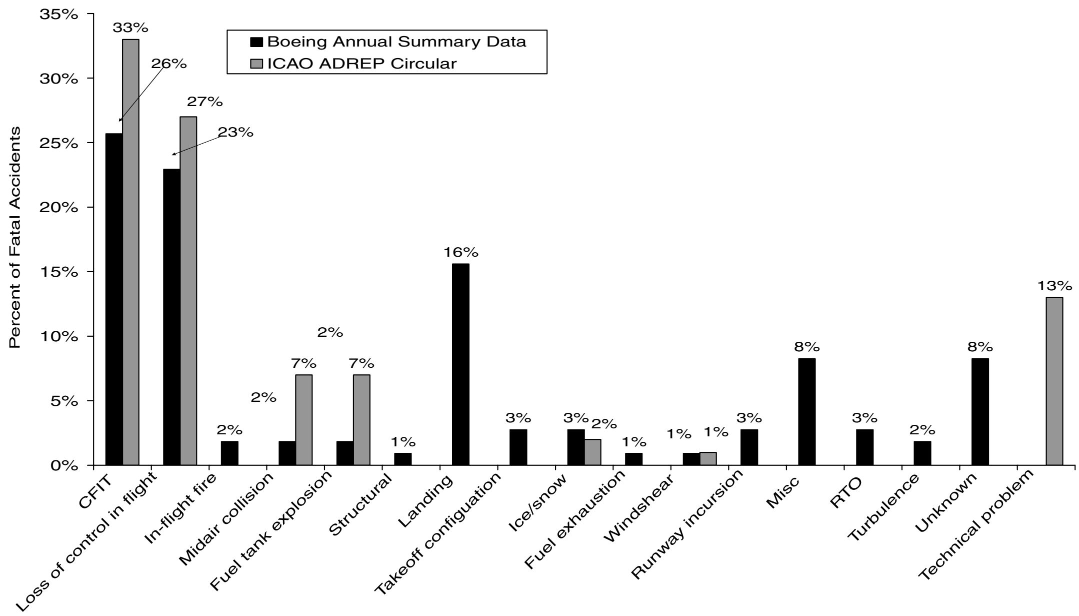

Fig. 1 Distribution of fatal accidents: Boeing and ICAO accident classification taxonomies, 2003.

technologically diverse industry segments is the tendency for identified safety priorities to be biased towards some global norm of all operations [1].

By aggregating the complete body of worldwide large-jet passenger transport fatal and hull loss accident data sets, the Boeing summary is biased toward some global norm of these operations. Figure 2 depicts the fatal and hull loss accidents in the Boeing summary adjacent to the same data controlled to include only U.S.-registered large-jet aircraft. Figure 2 clearly demonstrates that fatalities stemming from structural failure, fuel tank explosion, and in-flight fire each are of equal or higher relative importance as LOC-Flight and CFIT for the U.S.-registered operations [2].[‡] For the purposes of the Boeing Company, the data included in the summary are consistent with the aviation market segment with which Boeing competes. However, any assumption about either the criticality or applicability of CFIT or LOC-Flight as a priority in specific regions should be taken in context with the international perspective imbedded in the Boeing summary.

The current paper advances the aforementioned original work by furthering the discussion on the granularity of data incorporated in the safety summaries. The intent is to demonstrate that domestic aviation safety priorities may have been influenced by, and biased toward, global summaries of the already type noted. Subsequent broad-based, long-term safety initiatives influenced by such summaries would then be equally biased. This could minimize the applicability of identified safety priorities across regional, regulatory, or technological boundaries, including emerging aviation markets commonly cited in the industry literature as expected to use non-large-jet-type aircraft in commercial operations in nontraditional aviation markets [7–13].

II. Discussion

A. Drivers

Two primary drivers led to this comparative meta-analysis. The first was a retrospective look at the tenth anniversary of the 1997 release of the White House Commission's Final Report on Aviation Safety and Security [14]. The second was a comparative review of this final report with the 2002 Presidential Commission's Final Report on The Future of the United States Aerospace Industries [15].

The White House Commission's Final Report established a domestic fatal accident reduction goal of 80% in 10 years [14]. The Federal Aviation Administration (FAA) adopted, and has since reaffirmed, the goals set out in this document.[§] NASA issued a related goal of reducing the total (fatal and nonfatal) accident rate by a factor of 10 in 20 years.[¶] The White House Commission's Final Report made two critical observations: 1) "flight crew" is a primary driver for over 60% of all aviation accidents worldwide [14], and 2) 70% of all fatalities for the previous five years stemmed from LOC-Flight and CFIT accidents [14]. These primary drivers and accident classification observations are essentially identical to those of the annual Boeing Statistical Summary of Commercial Jet Airplane Accidents—Worldwide Operations [16]. This leaves the distinct impression that the Boeing summary was fundamental to establishing the accident reduction goals of the FAA and NASA.

The observations noted induced the authors of this paper to assess whether, by citing data from the Boeing summary, the FAA, NASA, and the White House Commission inadvertently transferred technical, regulatory, and geographic biases to identifying domestic commercial aviation safety priorities.

B. Analysis

Summaries of the aviation accident data set spanning two time frames are considered here. These time-frame choices were driven by the availability of the summaries included in this paper and are as follows:

1) Two summaries spanning 1960–2003 provide a long-term perspective. These summaries are the Boeing Statistical Summary of Commercial Jet Airplane Accidents 1959–2003 [2] and the ICAO ADREP Circular 297 [3]. These are not extended through 2006 because the ICAO ceased releasing the ADREP Circular after the 2002 release. The ICAO Annual Report 2004 [17] was used to update this data through 2003.**

2) Five summaries [2–6] spanning the decade 1990–1999 provide focus for a more detailed assessment of the longer time frame. The

[‡]Data available online at Aviation Accident Statistics, National Transportation Safety Board, http://ntsb.gov/aviation/Stats.htm [retrieved 1 April 2007].

[§]Data available online at the Federal Aviation Administration, http://www.whitehouse.gov/omb/expectmore/detail/10002246.2004.html [retrieved on April 1 2007].

[¶]Data available online at the National Aviation and Space Administration, Langley Research Center, http://www.dfrc.nasa.gov/Newsroom/X-Press/1997/xp-97-07-.html [retrieved April 1 2007].

**Data available online at ICAO/CAST Common Taxonomy, International Civil Aviation Organization–Commercial Aviation Safety Team, http://intlaviationstandards.org/index/html [retrieved April 1 2007].

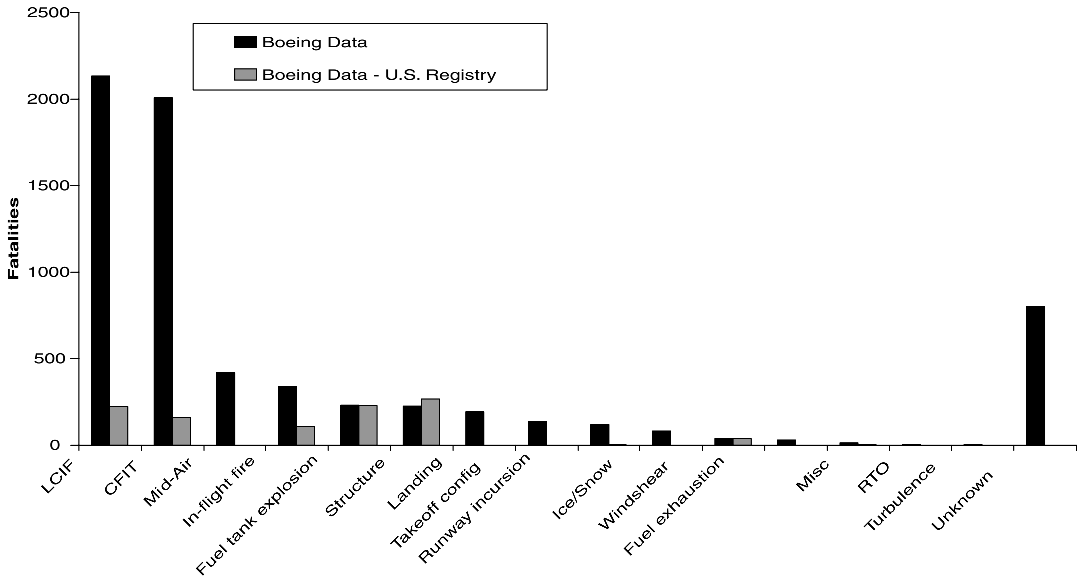

Fig. 2 Fatal accident classification comparison: world and U.S. registries, 1993–2002.

1990–1999 time frame is used despite the material being somewhat dated because multiple governmental and private entities used the end of the decade (and century) as a benchmark to examine 10 years of accident data.

In all, this paper considers five publicly available summaries. Table 1 lists these summaries and associated raw data sources. This table demonstrates that the five summaries share multiple data sources (except for the ICAO, which is based on accident reports submitted by member states [3]), which should serve to minimize any differences in the summaries sourced in the raw data.

Table 2 serves three functions. First, it outlines the methodology used for delineating data in the summaries of Table 1 by aircraft type, operation type, and accident characteristics. Second, it highlights the source of bias inherent in individual aviation safety data summaries due to methods of delineating the industry into subsegments. And third, it highlights the fact that some summaries are near subsets of others, but not identical. It is this third point that yields the opportunity to increase the resolution of each summary by performing a comparative meta-analysis; any differentials resulting from a direct comparison should be representative of industry segments incorporated in one summary but not the other(s). This method of comparative analysis is used in an iterative process to highlight industry segments that are effectively masked in specific safety summaries.

Table 1 Safety summary data sources

	Source of raw data[a]						
Summary producer	ICAO reports	Airclaims	AVSoft	Govt. reports	Press accounts	Operators	Manufacturers
ICAO				X			
Boeing	X		X		X	X	X
U.K. CAA		X					
The Netherlands	X	X	X				X
Flight International	X	X	X		X		X

[a]As cited in each summary.

Table 2 Delineation of aviation safety summaries (Source: Boeing 2003; NTSB 2003; ICAO 2003; U.K. CAA 2000; the Netherlands CAA 2000; Flight International 2000)

Delineation of accidents, fatalities, hull losses		ICAO	Boeing	U.K.	Netherlands	Flight Int.
Aircraft mass, kg	2.2–5.7 K					
	5.7–27 K	X		X	X	X
	>27 K		X			
Region of manufacture	Eastern				X	X
	Western	X	X	X		X
Schedule classification	Sched.	X	X	X	X	X
	Unsched.		X			
Engine type	Piston					
	Turboprop	X		X	X	X
	Jet		X	X	X	
Fatal accidents	Passenger	X	X	X	X	X
	Crew					
Military/terrorism/sabotage						X

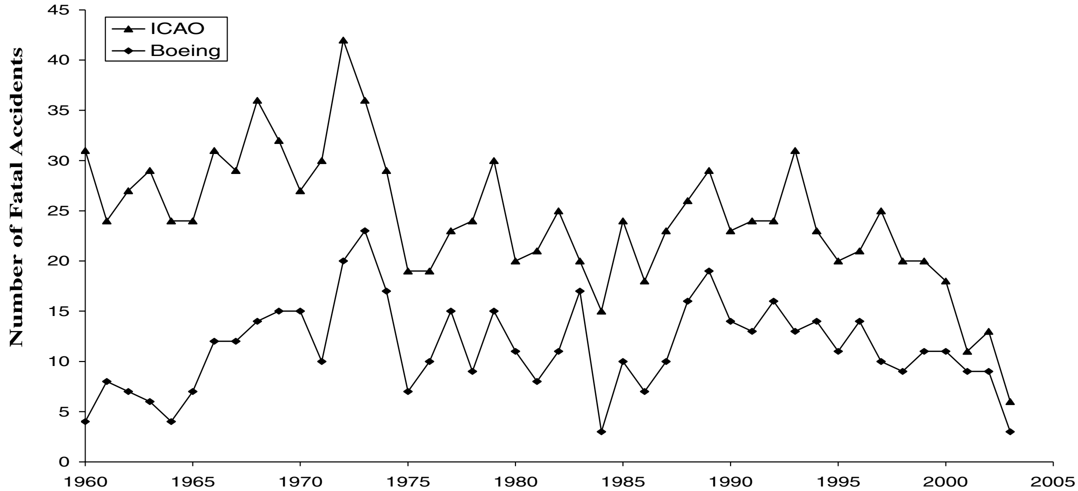

Fig. 3 Fatal Accidents: 1960–2003 (source: Boeing 2004, ICAO 2004).

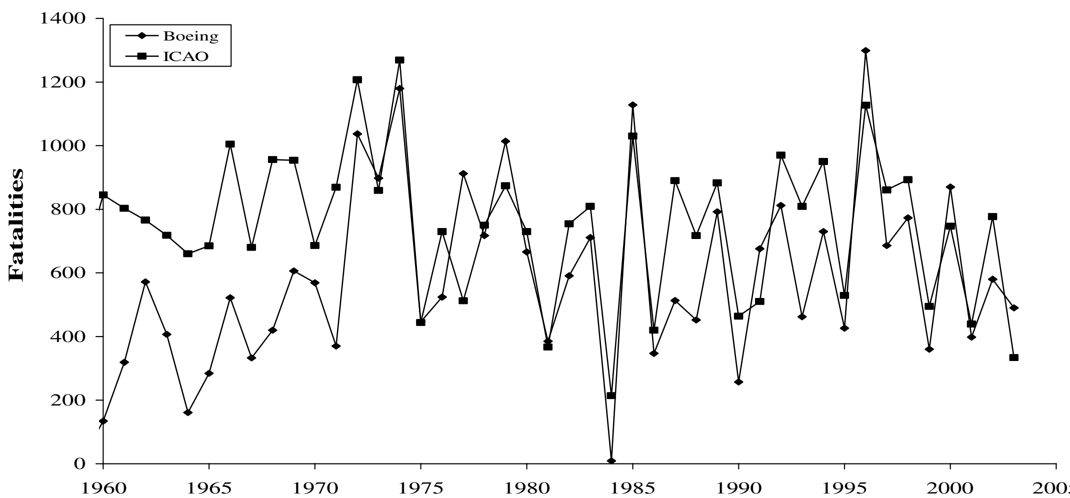

Fig. 4 Fatalities: 1960–2003 (source: Boeing 2004, ICAO 2004).

1. Fatal Accident Data: 1960–2003

Table 2 demonstrates that data contained in the Boeing summary are effectively a subset of the data contained in the ICAO summary. This is verified by plotting the data from these summaries (see Fig. 3). Note the significant long-term trend similarity, but notable short-term variations in the data. This long-term trend similarity would be expected if the Boeing data were truly a subset of the ICAO data. The correlation coefficient between the two data sets is a relatively low 0.55. This indicates that the covariance between the data sets might be taken as suspect. This moderate coefficient is likely explained by the sharp short-term variations in the two data sets, most notably in the years 1983, 1996, and 1997. A more complete review of the ICAO and Boeing data set for these years would need to be conducted to discern the cause of these differentials. For the purposes of this paper, it is sufficient to note that the Boeing summary includes unscheduled large-jet operations, but the ICAO summary does not. Despite these short-term anomalies, Table 2, Fig. 3, and the correlation coefficient do indicate that the Boeing data are a representative subset of the ICAO data over the long-term such that it is fair to compare the two summaries.

Figure 4 shows total fatality data from the Boeing and ICAO summaries. An immediately notable characteristic of Fig. 4 is the merging data sets. This trend would be expected if the large-jet segment of the aviation industry (the Boeing data) constituted a subset of the total fatal accident data set, but the singular majority of the total fatalities.

Such an assumption might seem intuitive when considering that the ramifications of failure associated with a large-jet accident (in terms of the potential number of fatalities per major accident) are significantly greater than those of smaller aircraft (below 27,000 kg MTOM). An initial review of Figs. 3 and 4 supports this assumption: the data merge when plotted as total fatalities because the large-jet segment of the industry constitutes the significant majority of fatalities in the worldwide civil aviation passenger transport industry. If this observation is substantiated, then, from the perspective of aviation safety (a global systems perspective), what benefits large-jet operations by definition benefits the aviation industry as a whole. This is a fair statement from the perspective that, despite the fact that approximately 50% of fatal accidents involve non-large-jet aircraft (see Fig. 3), the large-jet aircraft dominate Fig. 4. This suggests that non-large-jet aircraft contribute minimally to the fatality data record. If it can be demonstrated that this supposition is not correct, then a reliance on the Boeing or ICAO summaries in assessing safety priorities for a specific subsets of aviation could lead to unique industry characteristics and vulnerabilities being negated from the greater safety priority debate. This issue is investigated further in the next section by using additional safety summaries produced in 2000 that reviewed the decade 1990–1999.

2. Fatal Accident Data: 1990–1999

Multiple governmental, nongovernmental, and quasi-governmental organizations released safety summaries of the worldwide objective accident record similar to that of Boeing and the ICAO for the truncated 1990–1999 time frame [4–6]. These summaries were delineated into the same metrics of operations depicted in Table 2.

Similar to Fig. 2, when the data are plotted as total fatal accidents (see Fig. 5), the individual data sets assume a superposition that is dictated by the scope of the individual summaries; the more inclusive the summary, the greater the total number of fatal accidents included in the plot (as would seem intuitive). The most inclusive summary (Flight International [6]) dominates the figure, followed by the U.K. Civil Aviation Authority (CAA) [4], the Netherlands CAA [5], the ICAO [3], and Boeing [2] (respectively). A review of Table 2 would suggest that this is an expected result.

The data from the summaries of Fig. 5 are plotted again in Fig. 6 as total fatalities, yielding an interesting characteristic: the data do not merge as they did in Fig. 3 (when Boeing and the ICAO summary were plotted as total fatalities). Rather, in Fig. 6, three data sets (the U.K. CAA [4], the Netherlands CAA [5], and Flight International [6]) consistently track above the ICAO [3] and Boeing data sets [2].

The fact that the Boeing data are limited to fatalities sourced in large-jet aircraft accidents from a worldwide data set indicates that some nontrivial portion of the total fatality data set must be sourced in other industry segments. This counters the supposition that large-jet accidents constitute the dominate portion of fatalities, if not the majority of accidents. Furthering this point, Table 2 indicates that the ICAO summary contains a majority of all data fields, which leads to the assumption that the ICAO data set contains a majority of all fatalities. However, as is clear in Fig. 6, the ICAO summary contains a number of fatalities essentially equal to the Boeing summary. It is, therefore, not immediately clear in Fig. 6 which segment(s) of the industry is responsible for the differential between the ICAO and the U.K. CAA, the Netherlands CAA, and the Flight International plots. However, it is clear from Fig. 6 that approximately 50% of all fatalities are sourced in aviation accidents not included in either the Boeing or ICAO summaries. To assess what the source of the differential between these data sets, the following section juxtaposes the summaries depicted in Fig. 6 in greater detail.

3. *Differential Analysis*

To aid in the meta-analysis of the differential between the data sets in Fig. 6, the three summaries (the U.K. CAA, the Netherlands CAA, and Flight International) will be grouped and represented by the U.K. CAA summary. The U.K. CAA summary is then juxtaposed with the Boeing and ICAO summaries to discern the construct of the differential between the data sets. Representing the three with the U.K. CAA is fair because of the obvious similarity between the underlying data sets evident in Table 2 and Fig. 6. This is validated with correlation coefficients of 0.96 (the U.K. CAA relative to the Netherlands CAA), 0.99 (the Netherlands CAA relative to Flight International), and 0.97 (the U.K. CAA relative to Flight International).

The total fatalities for each summary in Fig. 6 are 11,793; 6481; and 7606 for the U.K. CAA [4], Boeing [2], and ICAO data sets [3],

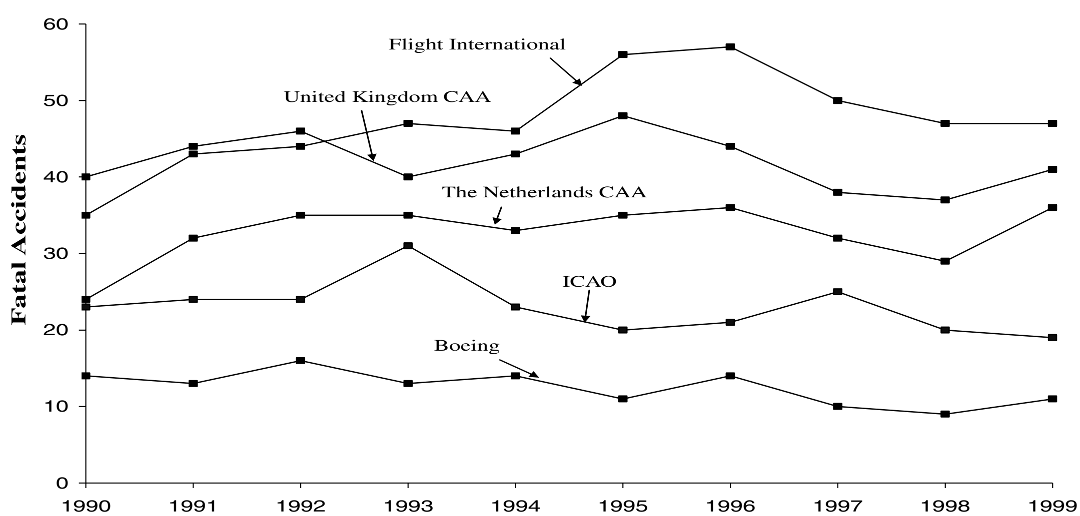

Fig. 5 Fatal Accidents: 1990–1999 (source: Boeing 2000, ICAO 2000, U.K. CAA 2000, the Netherlands CAA 2000, Flight International 2000).

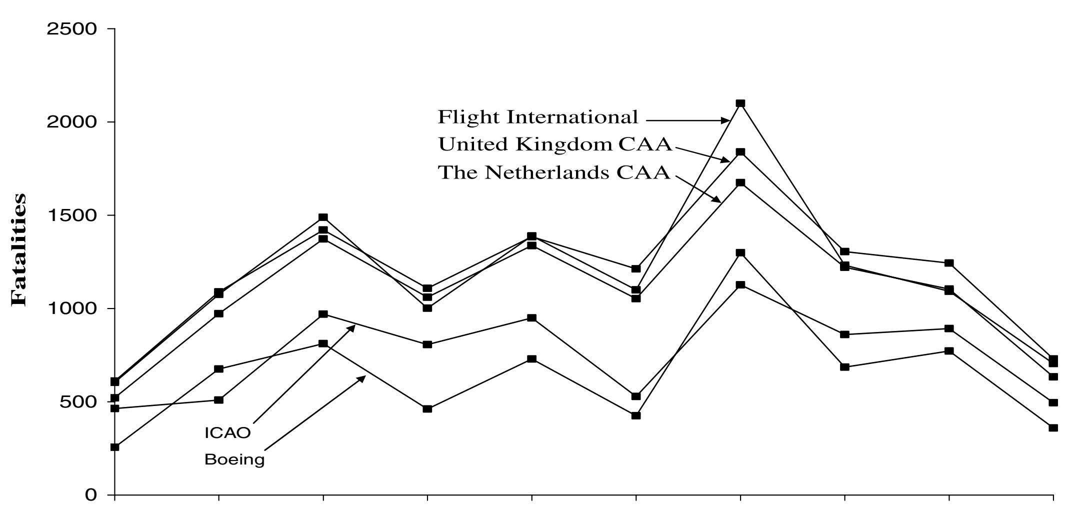

Fig. 6 Total fatalities; 1990–1999 (source: Boeing 2000, ICAO 2000, U.K. CAA 2000, the Netherlands CAA 2000, Flight International 2000).

Table 3 Construct of differential existing between summaries (source: Boeing 2003, U.K. CAA 2000, ICAO 2003)

Delineation of accident data		U.K. CAA	Boeing	Differential	U.K. CAA	ICAO	Differential
Aircraft mass, kg	2.2–5.7 K 5.7–27 K >27 K	X	X	U.K. CAA: >5.7 k, <27 K	X	X	ICAO: less than 2.7 K
Region of manufacture	Eastern Western	X	X	None	X	X	None
Schedule classification	Sched. Unsched.	X	X X	None	X	X	U.K. CAA: unsched.
Engine type	Piston Turboprop Jet	X X	X	U.K. CAA: turboprop	X X	X	ICAO: piston
Fatal accidents	Passenger Crew	X	X	None	X	X	U.K. CAA: crew

respectively. The total fatal accidents are 421, 125, and 230, respectively. The variations in these values are the direct result of the variation in the scope of each summary and, ultimately, the underlying data. Assuming that the U.K. CAA summary is the most inclusive (as Table 2 indicates), it might also be assumed that it is the most complete data set. Therefore, Figs. 5 and 6 collectively indicate that, relative to the Boeing/U.K. CAA juxtaposition, 45% of all fatalities and 70% of all fatal accidents are captured in the U.K. CAA but not the Boeing summary. Similarly, these figures indicate that, relative to the U.K. CAA/ICAO juxtaposition, 35% of all fatalities and 45% of all fatal accidents are captured in the U.K. CAA but not the ICAO summary.

To clarify these observations, the data of Table 2 are restated in Table 3 with the source of these differentials now highlighted. For the Boeing and the U.K. CAA summaries, the differential is sourced in jet aircraft between 5700 and 27,000 kg MTOM, as well as in turboprop driven aircraft of all MTOM (Table 3 shaded cells). For the ICAO and the U.K. CAA summaries, the differential is sourced in unscheduled operations of any aircraft MTOM, engine type, or region of manufacture. It is notable in Table 3 that the ICAO summary includes fatalities sourced in piston-engine driven aircraft accidents, whereas the U.K. CAA summary does not. However, because the U.K. CAA data set dominates the ICAO data in Fig. 5, these operations could not be the source of the differential. The differential would, therefore, be sourced in the unscheduled operations of all aircraft type and MTOM (see shaded cells).

III. Safety Priorities in Emerging Aviation Markets

The tables and figures presented in this paper have demonstrated three primary issues:

1) The priorities in aviation safety can be biased toward specific elements of the worldwide objective accident data record or toward some integrated global norm of operations.

2) Commercial aviation operations using small jet, turboprop, and piston driven aircraft constitute a nontrivial portion of the total worldwide objective accident data set.

3) Small jet, turboprop, and piston driven aircraft may not be proportionally represented in the aggregate of safety summaries.

Collectively, these three observations lead to the conclusion that subsets of global aviation operations that closely resemble CFR Title 14 Part 135 scheduled and unscheduled (typically smaller jet and nonjet aircraft) operations are not proportionally represented in influential summaries of the worldwide accident data record. Because these safety summaries have been shown to be drivers of long-term safety initiatives, the question raised here is, are emerging domestic aviation industries (commuter and air-taxi operations) adequately represented in safety analyses, with subsequent safety priorities identified? If the hazards and vulnerabilities of all aviation operations are similar, then the reasonable answer might be yes. However, if these emerging markets have unique hazard exposures and vulnerabilities, then the reasonable answer might be no.

To address this question, the remainder of this paper juxtaposes four data sets (in sets of two) as histograms. The supposition is that, if the histograms are similar in shape, accident trends are similar and, therefore, vulnerabilities and priorities are as likely to be similar. The counterargument will also be stated: if the histograms deviate, accident characteristics deviate and, therefore, vulnerabilities (and, ultimately, safety priorities) are as likely to deviate. Because of the nature of the available data, the resolution of this analysis is quite low and, thus, only general trends can be discussed. No specific safety priorities or metrics of vulnerabilities will be highlighted in definitive detail.

Figure 7 plots the data from the U.K. CAA [4] fatal accident summary against that of the Boeing [2] summary used in Fig. 1. The two summaries are juxtaposed because the former is a broad-based summary collecting data across geographical, technical, and regulatory boundaries, yielding a global-norm accident profile. The latter crosses geographic boundaries, but is constrained to a specific class of aircraft. A direct comparison can yield insight to the accident profiles of the underlying data.

Figure 7 demonstrates that CFIT and LOC-Flight are both critically important accident classifications. But there is one clear anomaly in the U.K. CAA summary: "collision" is the primary category for 54% of accidents, a category not included in the Boeing summary. Other deviations include a substantial increase in the percentage of LOC-Flight accidents and a substantial percentage of fatalities due to post-crash fire. From this figure, it could be argued that the differentiated shape of the histograms would suggest equally differentiated accident profiles and, likely, differentiated hazard vulnerability exposures.

There are limitations to this observation, and so it can not be stated that the accident profile differentiation is consistent with domestic operations. Therefore, to make more specific statements about domestic operations, 20 years of Part 135 accident data were reviewed and delineated using an accident classification histogram and the ICAO/Commercial Aviation Safety Team (CAST) Common Taxonomy.[††] This is then juxtaposed to large-jet accident data for domestic *N*-registered aircraft [18] and normalized by the total number of accidents (see Fig. 8). Two caveats should be noted. First, Part 135 fatal accidents reviewed were investigated and classified by the National Transportation Safety Board (NTSB) well before the existence of the ICAO/CAST Common Taxonomy. Accidents in this data set, therefore, were not necessarily assigned primary accident classifications that are directly transferable to the Common Taxonomy. The text of the individual accident reports were reviewed with the intent of assessing which Common Taxonomy accident category each accident might be allocated to. In some instances, there was ambiguity about which accident classification any particular accident should be allocated to. In such cases, every effort was made

[††]Data available online at Aviation Accident Statistics, National Transportation Safety Board, http://ntsb.gov/aviation/Stats.htm [retrieved 1 April 2007].

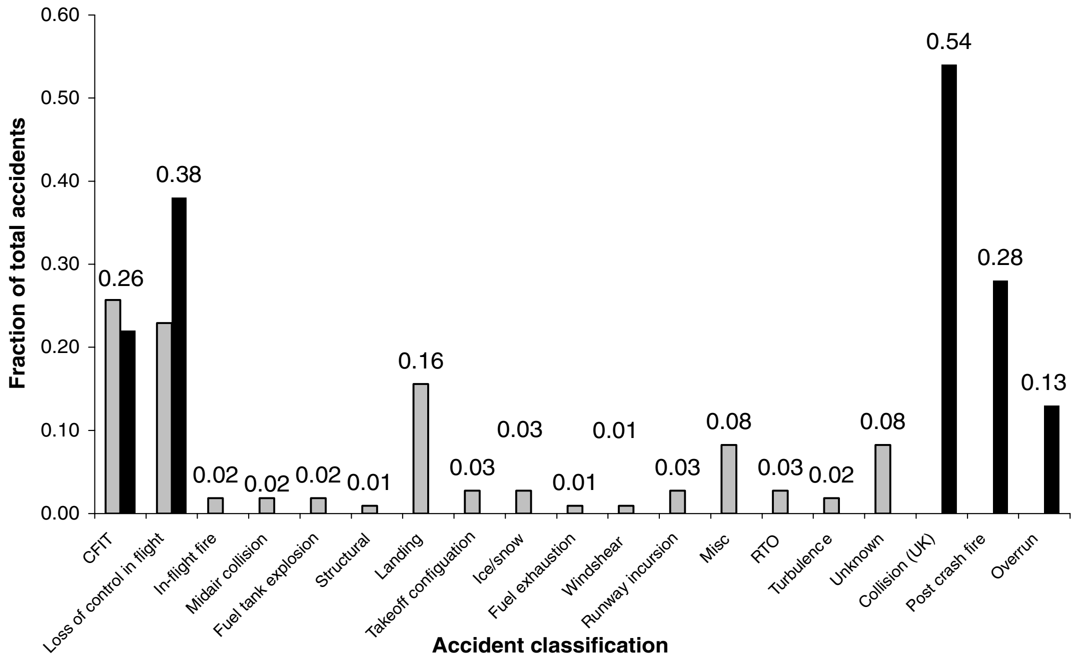

Fig. 7 Boeing and U.K. CAA: fatal accident classifications (source: Boeing 2003, U.K. CAA 2000).

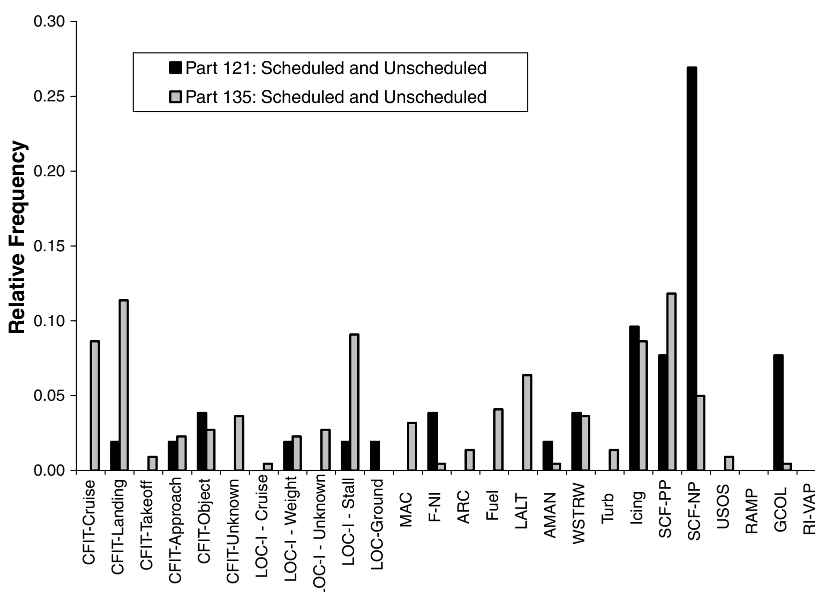

Fig. 8 Relative frequency distribution (source: NTSB accident data set, Boeing 2005).

Table 4 Five safety priorities for *N*-registered large-jet and Part 135 operations

	Accident categories with greatest proportion of total fatal and hull loss accidents							
N-registered large jet scheduled & unscheduled	——	——	——	Icing	SCF-PP	SCF-NP	GCOL	CFIT-Object F-NI WSTRW
Part 135: scheduled & unscheduled	CFIT-Cruise	CFIT-Landing	LOC-I Stall	Icing	SCF-PP	——	——	——

CFIT-Cruise: CFIT clearly noted as occurring during the cruise phase of the flight
CFIT-Landing: CFIT clearly noted as occurring during the landing phase of the flight but not hitting an object
LOC-I Stall: LOC-Flight accident clearly noted as occurring in-flight and caused by a stall
SCF-PP: system component failure, powerplant
SCF-NP: system component failure, nonpowerplant
GCOL: ground collision
F-NI: fire–smoke nonimpact
WSTRW: windshear thunderstorm

to fairly allocate individual accidents to the appropriate accident categories. (For example, the text of a sample NTSB accident report noted that there was no discernible cause for the accident. In this report, the accident was classified as loss of control in-flight. In Fig. 8, this accident is allocated to LOC-I Unknown.) Second, Fig. 1 demonstrated that *N*-registered large jets are involved in very few CFIT or LOC-Flight accidents. The data reviewed for this paper indicated that Part 135 operators were involved in substantially more. From the text of the accident reports reviewed, it was clear that delineating these accidents into subcategories of LOC-Flight and CFIT would benefit the discussion. Therefore, this comparative assessment of Part 135 and 121 accidents considers subcategories of CFIT and LOC-Flight (see Fig. 8). (Specific notations in the text of the NTSB accident investigation reports were the drivers to the greater delineation of CFIT and LOC-Flight fatal accidents into subcategories that included CFIT-Landing and LOC-Stall. For example, if reports cite CFIT accidents as striking objects or while landing, these are delineated as CFIT-Object and CFIT-Landing, respectively. This holds for LOC-Flight accidents, with stall or weight as examples.)

Figure 8 shows the five primary Part 135 accident categories: CFIT-Cruise, CFIT-Landing, LOC-Flight Stall, Icing, and Powerplant Failure. For *N*-registered large-jet operations, priorities are dominated by Non-Powerplant Failures and Other, whereas CFIT accidents trend towards zero. These are delineated in Table 4 for clarity. The deviation between the histograms of Fig. 8 is a leading indicator that Part 135- and 121-type operational subsets of aviation have measurably different accident profiles, an indication that each segment of aviation may hold equally different hazard and vulnerability exposures.

IV. Conclusions

The primary findings of this paper are that priorities in aviation safety (domestically or globally) are biased by accident trends specific to the global accident data dominated by the large-jet air transport category and that it is not clear whether identified safety priorities are transferable across geographic, technologic, or regulatory boundaries. These findings were developed through a comparison of accidents grouped into classifications by various entities concerned with aviation safety. Figures 1 and 2 noted that trends in accident classification will shift depending on the scope of the summary. Figures 3–6 demonstrated that individual non-large-jet fatal accidents may yield few fatalities, yet collectively the total number of accidents and fatalities comprise a nontrivial proportion of total fatal accidents and fatalities for the global commercial aviation industry. Figure 7 demonstrated that the proportional distribution of fatal/hull loss accidents by category will deviate depending on the scope of the data set. And Fig. 8 furthered the outcome of Fig. 7 by demonstrating a deviation in accident profiles between domestic Part 135- and 121-type operations.

Collectively, these figures demonstrate that the accident profiles of the two subsets of domestic operations each have some characteristics unique to the subset being observed. If the supposition of this paper is correct (that deviating accident profiles yield deviating hazard and vulnerability exposures), then the aggregate effect could include the safety needs of emerging markets being negated by the mass of data from the more dominate industry sector.

The relatively recent introduction of VLJs into the aviation market is expected to drive an expansion of Part 135 operations. The potential introduction of HVO at nontowered airports is also commonly cited as a driver for potentially significantly greater usage of these airports by Part 135 operations [8–13]. Collectively, the increased usage of Part 135 operators at towered and nontowered airports could lead to a paradigm shift in the risk exposure of domestic commercial passenger transport. A conclusion difficult to ignore is that a rapid development of these emerging aviation markets could outpace the capability to identify safety priorities that are currently biased toward some global norm of international operations. In a worst-case scenario, the increased usage of aviation markets that have no experience in high-volume operations (or possibly even commercial service) could drive an increase in either the absolute number of, or rate of, accidents. Subsequently, an increase in accident rates, even subtle a increase, could induce a perception of risk for individuals who are choosing a nontowered-based Part 135 air carrier as a travel option or who live near nontowered airports. In either case, perceived risk could cause a "push back" effect in the social acceptance of emerging aviation technologies as well as any subsequently emerging aviation markets. Such an effect could then impact the commercial air transport industry in the aggregate as the hub-and-spoke and national airspace nears any theoretical or practical capacity limits.

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