الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Aviation Safety Study

[Research Paper: SRP/0002/2020]

Injuries Caused by In-flight Turbulence

(United Arab Emirates Air Operators from 2015 to 2019)

Safety Studies are conducted in compliance with the *Air Accident and Incident Investigation Regulation* and conformance with Annex 13 to the Convention on International Civil Aviation (Chicago Convention). The final product of a Safety Study is a Research Paper, which may contain safety recommendations addressed to the appropriate organizations. Research Papers are made public on the website.

EXECUTIVE SUMMARY

Between January 2015 and December 2019, several flights operated by United Arab Emirates (UAE) air operators had encountered in-flight turbulence resulting in minor and serious injuries to passengers and cabin crewmembers. This Safety Study was initiated because there was an increasing trend in the number of injuries being reported.

In accordance with the definition of 'serious injury' in Annex 13 to the Chicago Convention, there were four such occurrences that were classified as 'accidents' because of serious injuries sustained by passengers and/or crewmembers, which resulted in investigations being conducted by the State of Occurrence and the State of the Operator. Out of these four accidents, the Air Accident Investigation Sector of the United Arab Emirates (AAIS) led and completed three of the investigations.

The investigation into the four accidents revealed that clear air turbulence was the only cause. Of the 57 people on-board who sustained injuries, 10 were classified as serious. The flight information regions (FIR) of Chennai (Bay of Bengal) and Jakarta (Indonesia) accounted for 75% of the in-flight severe turbulence encounters, 90% of the serious injuries, and 100% of the minor injuries. The severe turbulence encounters occurred mostly during the cruise between FL300 and FL400, during the period between May and October.

The rate of the four in-flight turbulence accidents was approximately one in every 550,000 departures.

The main data sources of this Safety Study were Reporting of Safety Incidents (ROSI) database; data provided by four main air operators in the UAE; and the AAIS investigation records.

Guidance for reporting safety incidents is provided by the General Civil Aviation Authority of the United Arab Emirates (GCAA) by the *Civil Aviation Advisory Publication* (CAAP) 22 (currently converted to Acceptable Means of Compliance "AMC"). Because of the differences in the interpretations of the CAAP 22 reporting criteria among the air operators subjected to this Study, there was a noticeable inconsistency between the ROSI database and the data provided by the operators.

ROSI database indicated that from 2015 to 2019, there were 100 reports of in-flight turbulence, containing information about 252 injuries (188 cabin crewmembers and 64 passengers) of which 16 were stated as serious.

The data provided by the four air operators indicated that out of the approximately 2.2 million departures performed within the same period, there were 581 in-flight turbulence occurrences that caused 904 injuries (692 cabin crewmembers and 212 passengers) of which 14 were serious injuries.

Overall, the 5-year in-flight turbulence data indicated that the rate of cabin crewmember's injuries occurred was about four times more than passengers' injury rate. This could be attributed to, most likely, that the crewmembers were engaged in passenger services at the moment the aircraft entered into the turbulent air volume.

The safety recommendations in this Study addresses issues related to cabin safety and ROSI mandatory reporting effectiveness for data analysis that can enhance the State Safety Program (SSP).

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CHAPTER 1. INTRODUCTION

1.1 What is Aviation Safety Study

Aviation Safety Studies conducted by the Air Accident Investigation Sector of the United Arab Emirates (AAIS) are initiated when an adverse safety trend, indicating a specific risk factor, is identified and an assessment of the existing situation is considered beneficial for safety improvement.

Safety Studies are sometimes carried out by the AAIS because of investigations conducted into similar occurrences, or into occurrences where the same operation or organization is involved.

Safety Studies cover a wide spectrum and are an effective tool for—

- analysis of an adverse safety occurrence trend;
- analysis of identified recurring factors in recent events;
- analysis of specific risk factors; and
- reporting on a specific aspect of safety interest.

The AAIS is responsible for the research, analysis, and conclusions contained in Safety Studies. The outcomes can lead to the AAIS issuing safety recommendations addressed to organisations and civil aviation authorities.

This Safety Study is triggered by a trend of injuries rate from 2015 to 2019 resulting from in-flight turbulence occurrences encountered by the four main air operators in the United Arab Emirates.

1.2 Objectives and Scope of this Safety Study

This Safety Study contains a statistical analysis of in-flight turbulence data, with a focus on in-flight turbulence occurrences that resulted in injuries to flight occupants. The target population of the study are the passengers and crewmembers who sustained minor or serious injuries during flights operated by four main United Arab Emirates operators during the period from January 2015 to December 2019

The ROSI e-reporting form lacked provisions for the reporter to enter in-flight turbulence occurrences' data relevant to injuries, the flight information region (FIR), or the involved air traffic control unit where the occurrences had taken place. This limitation constrained the scope of the Study.

In addition, the Study does not constitute an analysis of the effectiveness of the operators' policies and procedures relevant to flight planning, turbulence avoidance measures, crew training, or the involvement of safety management system (SMS), nor the analysis of aircraft airborne weather radar systems design and operations.

The objectives of the Study are to:

(a) Provide the aviation industry with statistical information about in-flight turbulences

(b) Evaluate the effectiveness of in-flight turbulence reporting;

(a) Identify means for utilizing the in-flight turbulence database for enhancing the effectiveness of the State Safety Program (SSP) of the United Arab Emirates.

1.3 Data Collection Method

For the period 2015 to 2019, injuries (serious and minor) related to in-flight turbulence was retrieved from the following sources:

(a) The in-flight turbulence occurrences involving UAE air operators that resulted in an accident investigation because of serious injury to a person on board;

(b) The GCAA mandatory reporting system called 'reporting of a safety incident (ROSI)';

(c) In-flight turbulence data from the four main UAE air operators.

Data was collected by:

(a) Interviews with the GCAA and the flight safety managers from four main UAE air operators;

(b) Distribution of a questionnaire developed for the Safety Study to the flight safety managers from the four main UAE air operators. All air operators had responded to the questionnaire.

(c) Review of ROSI data, provided by the GCAA, based on occurrences relevant to in-flight turbulence related to injuries.

CHAPTER 2. DEFINITIONS AND CATEGORISATION

2.1 General

In-flight turbulence is a known phenomenon, and it happens often. However, the severity of the turbulence varies in range within a range of light, moderate, severe, and extreme[1]. The consequences can lead to injuries to flight occupants as well as damage to the aircraft.

Assessment of in-flight turbulence severity refers to the flight crew perception of the situation, cockpit indications, and body sensation. In some circumstances, the assessment is subjective and more information are required to clarify the significance.

2.2 In-flight Turbulence

The International Civil Aviation Organization (ICAO) categorizes all in-flight turbulence encounters[2] under (TURB) acronym. This includes:

- Encounters with turbulence in clear air, mountain wave, mechanical, and/or cloud-associated turbulence;
- Wake vortex encounters; and
- Turbulence encountered by aircraft when operating around or at buildings, structures, and objects.

Flights into windshear or thunderstorm-related turbulence are coded as WSTRW.

The ICAO defines in-flight turbulence in clouds[3] as:

> "The irregular and instantaneous motions of air which is made up of a number of small eddies that travel in the general air current. Atmospheric turbulence is caused by random fluctuations in the wind flow. It can be caused by thermal or convective currents, differences in terrain and wind speed, along a frontal zone, or variation in temperature and pressure."

At high altitudes due to shear instabilities, an aircraft can be affected by clear air turbulence (CAT) in areas without significant clouds and away from thunderstorm activities. ICAO states[4] that "Clear air turbulence (CAT) is the bumpiness experienced by aircraft at high altitudes (normally above 18,000 feet)…" and "CAT is caused by eddy motion in the atmosphere which is a function of both time and space and occurs clear of clouds."

In this Study, all of the in-flight turbulence as a result of wake turbulence was because of wingtip vortices which are described by ICAO (reference footnote No. 4) as "A circular pattern of air current created by the movement of an airfoil through the air when the airfoil is generating lift"

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1 World Meteorological Organization https://community.wmo.int/activity-areas/aviation/hazards/turbulence

2 ICAO Accident/Incident Data Reporting (ADREP) Taxonomy 'Occurrence category' https://www.icao.int/safety/airnavigation/AIG/Pages/ADREP-Taxonomies.aspx

3 The ICAO ADREP definition for 'Turbulence' is based on the European Coordination Centre for Accident and Incident Reporting Systems ECCAIRS Aviation 1.3.0.12. The ECCAIRS Community Portal ceased operations on 01/01/2021. https://eccairsportal.jrc.ec.europa.eu/

4 ICAO ADREP Taxonomy 'Descriptive Factors' https://www.icao.int/safety/airnavigation/AIG/Pages/ADREP-Taxonomies.aspx

The following is a summary of the description of turbulence severity[5]:

- *Light turbulence* is the least severe, with slight, erratic changes in attitude and/or altitude. Passengers may feel slight strain against seatbelts, however, cabin crew would normally continue serving passengers.
- *Moderate turbulence* is of greater intensity with variations in speed as well as altitude and attitude may occur but the aircraft remains in control all the time. Walking and cabin service in the cabin becomes difficult with liquids splashing out of cups. Passengers will feel strain positive strain against seat belts.
- *Severe turbulence* is characterized by large, abrupt changes in attitude and altitude with large variations in airspeed. There may be brief periods where effective control of the aircraft is impossible. Walking in the cabin is not safe and impossible; passengers are forced violently against seat belts; unsecured occupants may impact cabin interior and maybe forcefully lifted off their feet; loose objects may move around the cabin; and damage to aircraft structures may occur.
- *Extreme turbulence* is capable of causing structural damage and resulting directly in prolonged, possibly terminal, loss of control of the aircraft.

2.3 Injury

This Study adopts the classification of injury severity as described in the Air Accident and Incident Investigation Regulation (AAIR) and Annex 13. The criteria of severity is defined as follows:

(a) *Serious Injury.* Is injury requiring hospitalization for more than 48 hours commencing within seven days from the occurrence in which a certain level of damage occurs to bone or internal organ, laceration causing haemorrhage, nerve, muscle or tendon damage; certain degree of burns; or exposure to infectious substances or injurious radiation.

(b) *Fatal Injury.* Any injury, which results in death within thirty days of the accident.

For the period 2015 to 2019, there were no fatal injuries as a result of in-flight turbulence.

In accordance with Annex 13, a fatal or serious injury is classified as an Accident. The definition of an Accident states:

> "An occurrence associated with the operation of an aircraft which, in the case of a manned aircraft, takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, or in the case of an unmanned aircraft, takes place between the time the aircraft is ready to move with the purpose of flight until such time as it comes to rest at the end of the flight and the primary propulsion system is shut down, in which:
>
> a) a person is fatally or seriously injured as a result of:
>
> — being in the aircraft, or
>
> — direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
>
> — direct exposure to jet blast,

5 Reference: Airbus technical digest publication FAST No. 18 June 1995 at https://www.airbus.com/content/dam/corporate-topics/publications/fast/FAST18.pdf and Airbus SE safety first publication – Managing Severe Turbulence https://safetyfirst.airbus.com/managing-severe-turbulence/

except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or

b) the aircraft sustains damage or structural failure which:

— adversely affects the structural strength, performance or flight characteristics of the aircraft, and

— would normally require major repair or replacement of the affected component,

except for engine failure or damage, when the damage is limited to a single engine (including its cowlings or accessories), to propellers, wing tips, antennas, probes, vanes, tires, brakes, wheels, fairings, panels, landing gear doors, windscreens, the aircraft skin (such as small dents or puncture holes), or for minor damages to main rotor blades, tail rotor blades, landing gear, and those resulting from hail or bird strike (including holes in the radome); or

c) the aircraft is missing or is completely inaccessible.

Note 1. For statistical uniformity only, an injury resulting in death within thirty days of the date of the accident is classified, by ICAO, as a fatal injury."

CHAPTER 3. REPORTING SYSTEMS IN THE UNITED ARAB EMIRATES

3.1 Mandatory Occurrence Reporting

The GCAA employs an on-line reporting system called Reporting of Safety Incidents (ROSI) which constitutes a platform for subscribers from air operators, maintenance and repair organisations, aerodromes, air navigation service providers to report occurrences. ROSI is the main database of the mandatory reporting system.

The GCAA developed guidance to industry in Civil Aviation Advisory Publication (CAAP) 22 – *Incident Reporting*[6]. CAAP 22 contained the following turbulence-relevant occurrences under mandatory reporting:

> "
>
> - Severe turbulence encounters resulting in injury to occupants or deemed to require a 'turbulence check' of the aircraft.
> - Wake turbulence encounters.
> - An incident, which have or could have led to significant injury to passengers or crew but which are not considered reportable as an accident under Annex 13.
> - Turbulence encounters resulting in injury to occupants or caused damage to aircraft
> - Any event involving injuries to crew/passengers."

CAAP 22 defines 'Injury' as:

> "An incident, which have or could have led to significant injury to passengers or crew but which are not considered reportable as an accident under Annex 13."

3.2 Air Accidents and Incidents Notification

Immediate notification of accidents and serious incidents to the AAIS Duty Investigator hotline +971 50 641 4667 was required by Civil Aviation Regulations (CAR) Part VI, Chapter 3 – *Air Accidents and Incident Investigations*, Section 4 – *Notification*[7], which stated:

> "
>
> - Any person who has knowledge of the occurrence of accident or serious incident shall immediately notify the GCAA.
> - All air operators, ATC units, approved maintenance organizations, aerodrome operators, and local civil aviation departments shall establish a system of "immediate notification of air accidents and serious incidents" to the GCAA."

[6] Effective 8 November 2020, CAAP 22 – Incident Reporting - was replaced by standalone Acceptable Means of Compliance 22 (AMC-22)

[7] March 2020, the AAIS published an Air Accident Investigation Directive (AAID02/2020) – Urgently Reportable Occurrences.

CHAPTER 4. INVESTIGATION OF IN-FLIGHT OCCURRENCES

Four investigations were conducted during the period from 2015 to 2019. Three of the investigations were conducted by the AAIS and one by the National Transportation Safety Committee of Indonesia as being the accident investigation authority of the State of Occurrence.

The four occurrences were classified as “accident” in accordance with Annex 13 classification due to their consequential serious injuries. Figure 1 illustrates examples of cabin interior damages because of passengers impacting the cabin ceiling during the in-flight turbulence occurrences.

Figure 1. Examples of cabin interior damages

Below extracts are from the Reports of the four investigations:

4.1 Severe Turbulence during Cruise

4 May 2016[8]

An Airbus A330 aircraft operating a scheduled passenger flight from Abu Dhabi International Airport (OMAA) to Soekarno-Hatta International Airport (WIII) Jakarta, Indonesia, with 12 crew and 262 passengers on-board, encountered severe turbulence during cruise at flight level FL390, 15 minutes prior to top of descent. The encounter lasted for approximately 22 seconds.

The significant weather chart, which was part of operational flight plan (OFP) briefing material for the pilots, illustrated possible thunderstorms and cumulonimbus (CB) clouds up to FL470 in Jakarta FIR above Sumatra Island where the turbulence was encountered. Along the flight path, the aircraft weather radar did not provide any indication of significant weather that may have alerted the flight crew to deviate or alert the cabin crew and passengers.

At the time of the turbulence, the seat belt sign was OFF and the cabin crewmembers were preparing for the arrival procedure. Some passengers were not fastening seatbelts.

The turbulence caused serious injuries to one cabin crewmember and six passengers. Three cabin crewmember and 14 passengers sustained minor injuries.

Several places in the forward and aft cabin ceilings sustained damages, but the most significant damage was in the aft cabin between seat rows 21 to 45.

[8] Reference: KNKT.16.05.13.04 Final Report, issued by Komite Nasional Keselamatan Transportasi, Republic of Indonesia on 28 December 2017.

The investigation determined the contributing factor was:

"

- The aircraft was flying outside the visible cloud which was within the turbulence area of the thunderstorm.
- The turbulence was not anticipated and no warning provided to the cabin crew and passengers."

The safety recommendations addressed to the operator in the Final Report were about developing measures for thunderstorm risk mitigation, enhancing safety reminders for passengers to fasten seatbelts when seated, and making post-occurrence safety brief among the flight and cabin crews.

The National Transportation Safety Committee of Indonesia led this Accident investigation and issued the Final Report.

10 July 2019[9]

An Airbus A380 aircraft operating a scheduled passenger flight from Auckland Airport (NZAA), New Zealand, to Dubai International Airport (OMDB), the United Arab Emirates, with 29 crew and 378 passengers on-board, encountered light to severe air turbulence in the FIR of Chennai, India, over the Bay of Bengal and lasted for about four minutes.

The air turbulence occurred during the cruise at FL400 in an area affected by convective activity with isolated embedded CBs. The flight crew stated that the weather radar did not indicate on the navigation display any precipitation along the aircraft flight path.

During the turbulence, the maximum operating speed was momentarily exceeded. The aircraft autopilot and autothrust remained engaged during the turbulence.

About five minutes before the aircraft encountered the turbulence, the flight crew turned the passengers' seatbelt signs to ON. Most of the cabin crewmembers were not aware that the seatbelt sign was ON and no announcement was made for passengers to return to their seats and fasten seatbelts.

Twenty-seven persons suffered injuries: 13 passengers and 13 cabin crewmembers sustained minor injuries, and one passenger sustained serious injury.

Four of the minor injured cabin crewmembers were in the business class aft galley. However, they were relieved from duty for the remainder of the flight. Another seven cabin crewmembers were in the crew rest during the turbulence where their body reaction to the turbulence caused their heads to impact the ceiling of the compartment.

A passenger, who was in the aft cabin lavatory at the time of turbulence, sustained a serious injury when she was lifted off her feet causing her head to impact the ceiling of the lavatory. Medical examination confirmed that the passenger had sustained a fracture to her neck first cervical vertebra.

The AAIS issued six safety recommendations in the Final Report addressed to the operator and the aircraft manufacturer. They highlighted concerns related to flight planning, handholds in the cabin, crew rest compartment safety during turbulence, and the flight crew manuals and alerting system relevant to wet turbulence detection.

[9] Reference: AIFN/0009/2019 Final Report, issued by the AAIS on 12 August 2020.

1 October 2019

A Boeing 777 aircraft operating a scheduled passenger flight from OMDB to I Gusti Ngurah Rai International Airport (WADD), Bali, Indonesia, with 17 crew and 326 passengers on-board, encountered severe turbulence during cruise at FL350 in Singapore FIR within Indonesia State territory.

There was no weather radar echo of precipitation displayed on the navigation display. During the turbulence, the autopilot disengaged twice. The flight crew attributed the turbulence to the aircraft transiting the top of an embedded thunderstorm.

Prior to the turbulence, the seatbelt signs were turned ON.

Four passengers sustained minor injuries and one cabin crewmember sustained serious injury.

Several cabin ceiling panels were damaged and some passenger oxygen masks dropped.

The National Transportation Safety Committee of Indonesia led this Accident investigation, which is still ongoing.

4.2 Severe Turbulence during Descent[10]

On 13 September 2015, an Airbus A380 aircraft operating a scheduled passenger flight from King Abdulaziz International Airport (OEJN), Jeddah, Saudi Arabia, to OMDB, with 27 crew and 159 passengers on-board, encountered severe air turbulence that lasted for about four seconds approximately twenty minutes before landing. The aircraft was descending through FL300.

During the descent, the flight crew stated that there were no significant weather returns displayed on the navigation display. The flight crew stated that there was a thin layer of scattered clouds and after descending through this layer, they observed a small single cloud ahead of the aircraft. The commander, who was the pilot monitoring, estimated this cloud to be less than one mile in diameter. The commander instructed the copilot (pilot flying) to establish a right turn and then requested a weather deviation from air traffic control (ATC). The weather deviation request was denied by ATC due to airspace conflict.

At the time of the turbulence, the seatbelt sign was ON and the cabin crew were securing the cabin in preparation for landing.

The aircraft experienced g-loads that reached up to positive 2.2 g. As a result, a cabin crewmember, who was in a place adjacent to the upper deck right passenger door UR1, sustained a fracture to the right ankle. Nine other cabin crewmembers sustained minor injuries.

The AAIS issued one safety recommendation addressed to the air operator in the Final Report concerning risk assessment severity for the type of cabin crew shoes during critical phases of flight.

[10] Reference: AIFN/0009/2015 Final Report, issued by the AAIS on 19 October 2017.

CHAPTER 5. ROSI DATA OF IN-FLIGHT TURBULENCE DURING THE PERIOD FROM 2015 TO 2019

5.1 Reported occurrences per year

During interviews with the safety managers of the four air operators, they expressed their interpretation of the in-flight turbulence reporting requirement through ROSI to include:

(a) All severe air turbulences;

(b) All wake turbulences;

(c) All fatal and serious injuries to aircraft occupants; and

(d) Aircraft damage.

The ROSI on-line reporting form does not contain a provision for reporting the number of injured occupants and severity of the injury. The only place where such data is the free text box under the '*Description of the Incident'* field.

The review of the ROSI database revealed that a total of 100 in-flight turbulence occurrences (wake and air turbulence) were reported by the four air operators. These reported occurrences included cases of injuries to flight occupants and/or aircraft interior damage. There was no aircraft exterior damage reported. Table 1 illustrates the number of reports per year.

Table 1. ROSI 2015-2019 data: Number of turbulence occurrences resulting in injuries

Year	2015	2016	2017	2018	2019	Total
Number	21	20	17	20	22	100

5.2 Direct cause

Table 2 illustrates the type of in-flight turbulence as stated in the ROSI file.

Table 2. Direct cause for the in-flight turbulence

Year	2015	2016	2017	2018	2019	Total
Wake	11	9	10	6	2	38
Air	10	11	7	14	20	62
Total	21	20	17	20	22	100

5.3 Flight phase

Table 3 illustrates the in-flight turbulence occurrences during a flight phase.

Table 3. In-flight turbulence occurrences phase of flight

Year	2015	2016	2017	2018	2019	Total
Climb	2	5	3	4	2	16
Cruise	18	11	12	12	14	67
Descent	1	3	2	3	6	15

Approach	0	1	0	1	0	2
Total	21	20	17	20	22	100

5.4 Injuries

The 100 ROSI reports indicated that 252 (188 cabin crewmembers and 64 passengers) had sustained minor or serious injuries. Out of the 252 injuries, 16 (9 cabin crewmembers and 7 passengers) were classified as serious. The data was retrieved through a search for "injury, injuries, turbulence" keywords in the free text box of the '*Description of the Incident'* part in the on-line reporting form.

Table 4 lists the number of injuries (minor and serious) per year.

Table 4. Number of injuries per year						
Year	2015	2016	2017	2018	2019	Total
Total	39	51	32	50	80	252

Table 5 illustrates the phase of flight when the 252 in-flight turbulence injuries had occurred, and the number of injuries during each flight phase.

Table 5. Number of injuries by flight phase					
Flight phase	Climb	Cruise	Descent	Approach	Total
Total	28	193	29	2	252

5.5 Aircraft type

As illustrated in figure 2, of the 100 ROSI reported occurrences, 88 wide body aircraft were involved.

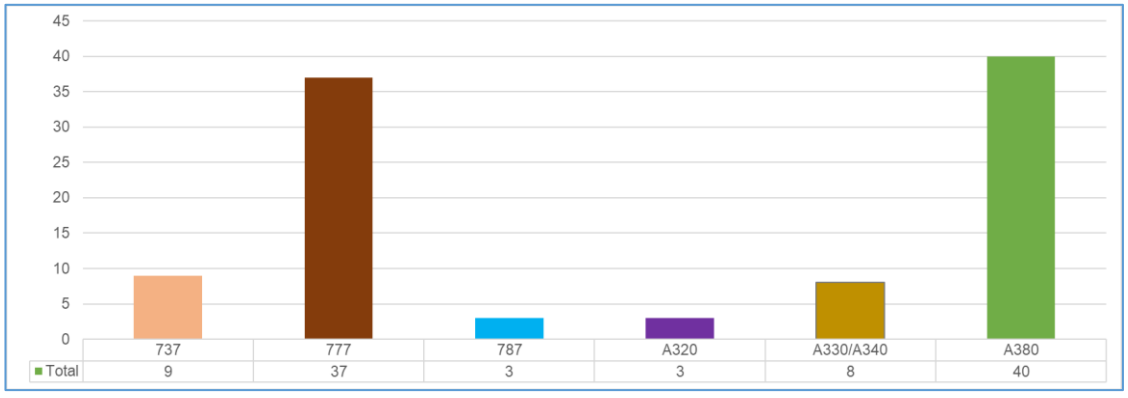

Figure 2. Turbulence with injuries by aircraft type (2015-2019)

5.6 Turbulence occurrences and injuries distribution by FIR

The ROSI reports lacked data about the flight information region (FIR) where the turbulence encounters had occurred. This constrained the scope of the study.

CHAPTER 6. AIR OPERATOR'S DATA OF IN-FLIGHT TURBULENCE OCCURRENCES DURING THE PERIOD FROM 2015 TO 2019

As a common practice within the four operators, air safety reports (ASR) are submitted by the flight crew to the operators' safety units. The operator's safety unit then perform a risk assessment of the ASR and determine if the occurrence is reportable to the GCAA ROSI system.

The four air operators provided information for this Study, based on the ASRs, for flights encountering in-flight turbulence that resulted in injuries. However, there was a shortage of data relevant to the in-flight turbulence:

- Place in reference to FIR;
- Place of the injured occupants in reference to the cabin configuration;
- The time length of the sick leave of the injured cabin crewmember;
- Inspection and repair accomplished tasks for returning the aircraft to service;

The following is a summary of the in-flight turbulence occurrences that took place within the 2015-2019 period, as provided by the four operators:

(a) The first operator had accomplished 326,495 departures with 2.67 hours average flight time. There were seven in-flight turbulence occurrences resulting in seven minor injuries (5 cabin crewmembers and 2 passengers). Six of the occurrences took place during cruise and one during descent. The direct cause of the in-flight turbulence was not determined.

(b) The second operator had accomplished 956,641 departures with 5.59 hours average flight time. There were 435 in-flight turbulence occurrences resulting in 701 injuries (521 cabin crewmembers and 180 passengers). Three of the injuries were classified as serious (2 cabin crewmembers and 1 passenger). The database indicated that 370 (85%) of the reported turbulence took place during the cruise phase of flight. The turbulence was categorized as air turbulence for 402 (92%) occurrences and wake turbulence for 33 (8%).

(c) The third operator had accomplished 516,487 departures with 5.05 hours average flight time. There were 96 in-flight turbulence occurrences which resulted in 138 injuries (112 cabin crewmembers and 26 passengers), out of which 7 were classified as serious (1 cabin crewmember and 6 passengers).

Of the 112 injured cabin crewmembers, 90 were relieved from duty for a collective of 506 sick leave days. Turbulence during the cruise phase accounted for 72 (80%) of the reported turbulence. The main direct cause of the turbulence occurrences was air turbulence which accounted for 86 (90%) and 10 wake turbulence.

(d) The fourth operator had accomplished 419,272 departures with 2.63 hours average flight time. During this period, there were 43 in-flight turbulence occurrences resulting in 58 injuries (54 cabin crewmembers and 4 passengers), out of which 4 injuries were classified as serious (all were cabin crewmembers). Out of the 58 injuries, 38 (66%) injuries occurred in the galleys. The injured cabin crewmembers were relieved from duty for a collective 625 sick leave days.

Twenty-seven (63%) of the reported turbulence occurrences took place during descent, and 20 of them were in the FIR of United Arab Emirates to OMDB destination. The database showed that 11 out of the 43 (26%) in-flight turbulence occurrences took place in cruise phase. The main direct cause for turbulence was air turbulence which affected 31 (72%) flights. Wake turbulence affected 12 flights.

CHAPTER 7. ANALYSIS OF THE IN-FLIGHT TURBULENCE DATA

7.1 Investigations of In-flight Occurrences involving United Arab Emirates Air Operators

During the period from January 2015 to December 2019, the four air operators subjected to this Study had accomplished about 2.2 million departures in total. The rate of severe in-flight turbulence occurrences that resulted in serious injuries (which were classified as accidents in accordance with Annex 13) was approximately 1 for every 550,000 departures.

The four investigated in-flight turbulence occurrences had resulted in 57 injuries to the occupants (19 cabin crew and 38 passengers). Ten of the injuries were classified as serious (3 cabin crew and 7 passengers), whereas the remaining 47 injuries were minor (16 cabin crew and 31 passengers).

The flight crews of the four investigated occurrences attributed the in-flight turbulence to 'clear air turbulence' in air volumes affected by convective weather. For their perception, the crews relied on the fact that the aircraft weather radar echo returns did not indicate any significant clouds along the flight path.

Prior to the severe turbulence encounter, the flight crews had turned the seatbelt sign ON for three of the four occurrences.

The seriously injured occupants in these accidents sustained fractures mainly to the leg with one passenger sustaining a fracture to a neck bone. All fractures were due to passengers or cabin crewmembers being unrestrained. The affected occupants were mainly positioned in the galleys and lavatories located in the aft cabin. Due to the aircraft g-loads during the severe turbulence encounter, most persons were lifted off their feet and either sustained the injury by lift and drop on the floor or impacting the cabin ceiling. Minor injuries included lacerations and bruises.

There was no information provided by the air operators for the inspection and repair tasks to return the aircraft to service.

7.2 ROSI Data

The ROSI e-reporting form lacked specific fields for essential reporting data such as:

- the category and cause of in-flight turbulence[11];
- the severity of the turbulence;
- the place of occurrence by FIR;
- the number of injured flight crew, cabin crew and passengers;
- the severity of the injuries;
- the location on the aircraft the injury occurred; and
- aircraft damage.

Alternatively, reporters had to enter arbitrary information to the free text box in the *Description of the Incident* field which may undermine the accuracy and validity of data because of

[11] Reference: ICAO ADREP Taxonomy https://www.icao.int/safety/airnavigation/AIG/Pages/ADREP-Taxonomies.aspx

overlooking primary information due to typo error in data entries. By nature, searches made through free texts are vulnerable because of using keywords that may not match with the erroneous, nonstandard, or mistakenly typed entries.

Missing such provisions for data entry have not only constrained the scope and objectives of this Study, but it has deprived the safety analysis capabilities of essential aspects that could have identified latent hazards related to issuance of NOTAMS, flight briefs, airspace seasonal conditions, cabin safety and crashworthiness, and flight and cabin crew reactions.

Because several of the 100 ROSI reports was missing the geographical location of the turbulence encounter, it was not possible to accurately determine the FIR location that would have benefited this Study. The classification of the injury severity was done by the air operator.

In summary, based on the information stated in the *Description of the Incident,* the 100 ROSI reports that were submitted by the four operators revealed the following statistical data collected during the period 2015-2019:

(a) Out of the 252 injuries, the injuries of 236 (179 cabin crewmembers and 57 passengers) were minor, and 16 (9 cabin crewmembers and 7 passengers) were serious.

(b) Cabin crewmembers accounted for 75% of the reported injuries.

(c) The year 2019 had the maximum number of injured occupants (80, about 32%);

(d) The cruise phase of flight had the maximum number of in-flight turbulence incident reports (67, 67%);

(e) The cruise phase of flight had the maximum number of injuries (193, about 77%);

(f) Air turbulence was the main significant reason for the reported turbulence occurrences (62, 62%);

(g) Wake turbulence accounted for 38 of the occurrences (38%);

(h) The four occurrences that were subjected to investigations were reported by the air operators.

7.3 Air Operators' Data

For the 5-year period, the aggregate of the four air operators' in-flight turbulence occurrence data indicated that:

(a) There were 2,218,895 total departures.

(b) 581 flights had an in-flight turbulence encounter that resulted in 904 injuries (682 cabin crewmembers and 212 passengers) of which 14 were serious (7 each cabin crewmembers and passengers).

(c) A rate of 1 in-flight turbulence occurrence for about every 3,800 departures, resulting in injuries.

(d) Cabin crewmembers accounted for 77% of the reported injuries.

(e) One air operator accounted for the maximum number of passengers' injuries (180, 85%).

(f) The majority of injuries (465, 80%) had resulted from occurrences that took place during the cruise phase of flight.

(g) Air turbulence had accounted for 517 (89%) of the in-flight turbulence occurrences resulting in injuries.

Except for one of the four air operator who reported data about the place of the turbulence within FIR during cruise, descent, approach and landing phases of flight, the other three air operators did not provide such data. The lack of such data restricted the ability to determine the territory of the State of Occurrence which is essential information for identifying the obligations of the States concerned in the occurrences according to the protocols of Annex 13.

Of the 692 cabin crewmembers who sustained injuries over the 5-year period, only two of the air operators provided data relevant to the number of days' the cabin crewmembers had been relieved from duty because of their injuries.

Figure 3 illustrates the combined data of the four main air operators. The rates are calculated as the ratio of the number of in-flight turbulence occurrences (resulting in injuries) as well as the number of injuries per 100,000 departures

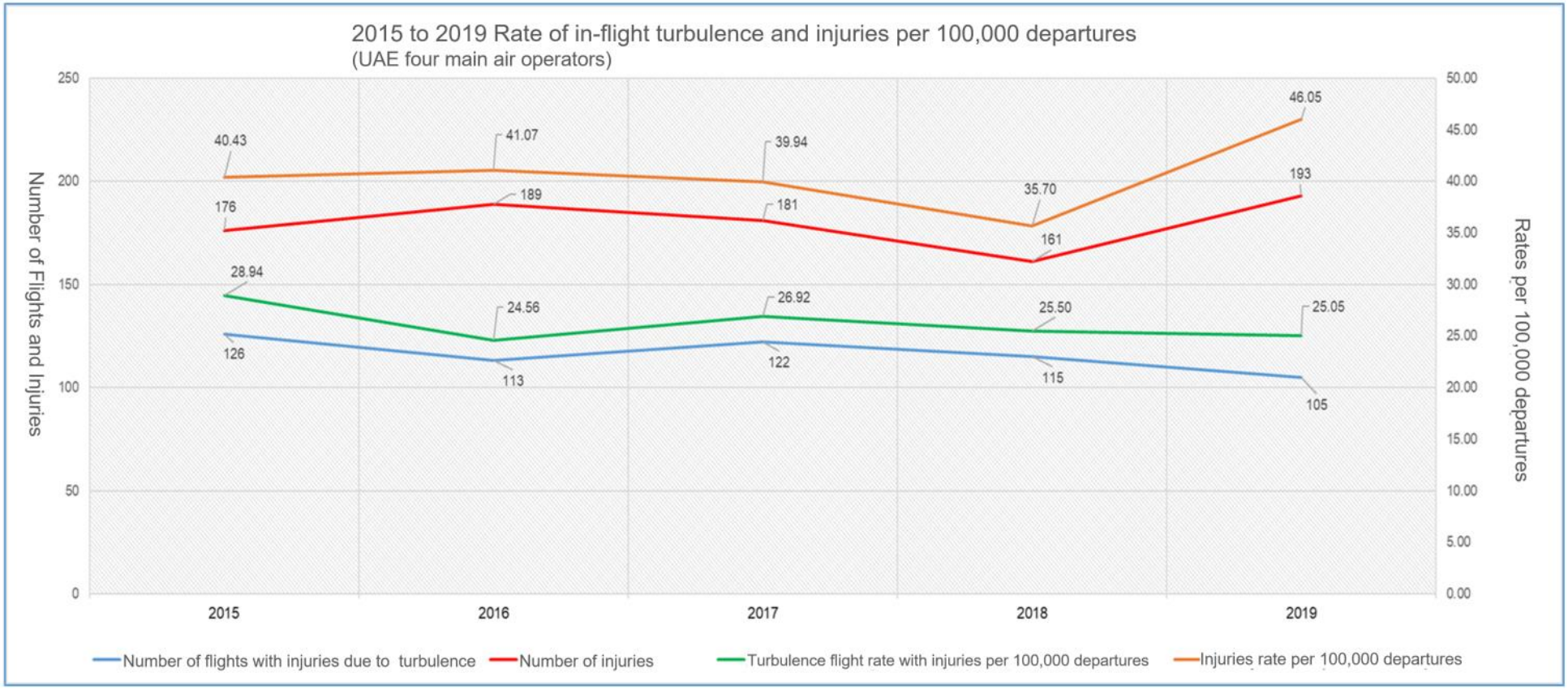

Figure 3. Number of in-flight turbulence occurrences with injuries and rates per 100,000 departures ((Aggregate of the four air operators)

CHAPTER 8. CONCLUSIONS

8.1 Unlike wake turbulence, which is systematically prevented by vicinity separation procedure, clear air turbulence is a latent safety threat that cannot be, in most times, unveiled until an event takes place. For UAE operators, this Study has indicated that clear air turbulence accounted for the majority of the direct cause for the in-flight turbulence.

8.2 A significant number of injuries to flight occupants (cabin crewmembers and passengers) had been reported during the period 2015-2019. This Study has indicated that UAE air operators leading cause of serious and minor injuries in non-fatal accidents are because of in-flight turbulence.

8.3 The accident investigations that were conducted on the in-flight turbulence occurrences concluded that the four cases were clear air turbulence occurrences.

The FIRs of Chennai (Bay of Bengal) and Jakarta (Indonesia) accounted for 75% of the in-flight severe turbulence encounters, 90% of the serious injuries, and 100% of the minor injuries. The severe turbulence encounters occurred between FL300 and FL400, during flights operated between the months of May to October. Three of the four severe turbulence occurrences took place during the cruise phase of flight.

8.4 The air operators' interpretation of the guidance material for mandatory reporting published by the GCAA (CAAP 22) had not contemplated the operators to report all in-flight turbulence encounters that resulted in injury to flight occupants. The lack of common understanding burdens the achievement of the occurrence reporting objective as stated in CAAP 22 "to contribute to the improvement of flight safety by ensuring that relevant information on safety is reported, collected, investigated, analysed, stored, protected and disseminated."

8.5 There was a significant difference between the State's mandatory reporting system (ROSI) and the databases of the four operators. For the period 2015-2019, ROSI database revealed 100 in-flight turbulence occurrences resulting in 252 injuries, whereas the databases of the four air operators contained 581 occurrences resulting in 904 injuries. Differences were also noted in the number of serious injuries as ROSI had 14 and the air operator's data stated 16.

8.6 The databases of the four operators indicated that the number of injured cabin crewmembers was four times the number of injured passengers. This is most likely because cabin crew are usually unrestrained during the occurrence of unpredicted turbulence whilst performing their normal duties during the flight. The cruise phase of flight had 80% of the in-flight turbulence encounters as well as the most number of injuries to both passengers and cabin crewmembers. Air turbulence accounted for 75% of the direct cause for in-flight turbulence.

CHAPTER 9. SAFETY RECOMMENDATIONS

Based on the conclusions of this Safety Study, the Air Accident Investigation Sector (AAIS) addresses the following recommendations.

The General Civil Aviation Authority of the United Arab Emirates (GCAA):

SSR37/2021

Safety recommendation SR76/2020 addressed by the AAIS final report AIFN/0009/2019, issued on 12 August 2020, recommended that the operator "Standardize and improve the accessibility of the lavatory handholds, the accessibility and identification of handholds in the wet and dry galleys and the accessibility of the handholds in the showers."

Similarly, as stated in FAA *Advisory Circular AC No. 120-88A – Preventing Injuries Caused by Turbulence* – recommends:

> **"CABIN MODIFICATIONS.** An air carrier can consider cabin modifications such as handholds, restraints, or other devices to reduce injuries caused by turbulence. When an aircraft encounters unanticipated turbulence, there may not be time for preparation by crewmembers or passengers. In this situation, aircraft design is most likely to prevent or mitigate injuries caused by turbulence."

The AAIS recommends that the GCAA in consultation with the UAE air operators and aircraft manufacturers, perform a risk-based case study to identify the possibilities of mitigating crew injury risk caused by in-flight turbulence through appropriate cabin modifications.

SSR38/2021

Analysis of data submitted through the ROSI system is a useful input for the State risk management as a component of State Safety Program (SSP). For making the SSP more effective, ROSI system should be modified to facilitate more accurate data according to well-defined taxonomy.

Therefore, the GCAA is recommended to review the ROSI e-reporting form for the purpose of including additional fields for reporting in-flight turbulences. As appropriate, the fields are recommended to be formatted as a taxonomy drop list for selecting the severity of the in-flight turbulence, its type/category/cause, number as well as the severity of injuries sustained by crewmembers and passengers, location of the injured occupants in reference to the cabin configuration, place od occurrence within FIR, and damage to the aircraft.

SSR39/2021

The ROSI database contained 100 in-flight turbulence occurrences reported during January 2015 to December 2019, resulting in 252 injuries, whereas the databases of the four air operators subjected to this Safety Study contained 581 in-flight turbulence occurrences resulting in 904 injuries.

Even though the recent AMC 22 (which replaced CAAP 22 which was current at the date of issuing this Safety Study) already requires reporting of "any event involving injuries to crew/passengers", the GCAA is recommended to improve the AMC towards more clarity to the air operators to report injuries caused by in-flight turbulence to the GCAA through ROSI system.

LIST OF REFERENCES

- The General Civil Aviation Authority. “E-Publications”. www.gcaa.gov.ae
- UAE Civil Aviation Régulations CAR Part VI – Chapter 3 Air Accidents and Incidents Investigations
- The GCAA Civil Aviation Advisory Publication 22 (CAAP 22) – Incident Reporting*

  *Effective 8 November 2020, CAAP 22 – Incident Reporting - was replaced by standalone Acceptable Means of Compliance 22 (AMC-22)
- Annex 13 to the Chicago Convention ─ Aircraft Accident and Incident Investigation
- Federal Aviation Administration of the United States Advisory Circular AC No. 120-88A – Preventing Injuries Caused by Turbulence
- World Meteorological Organization https://community.wmo.int/activity-areas/aviation/hazards/turbulence
- Federal Aviation Administration (FAA) of the United States https://www.faa.gov/travelers/fly_safe/turbulence/
- Airbus technical digest publication FAST No. 18 June 1995 at https://www.airbus.com/content/dam/corporate-topics/publications/fast/FAST18.pdf.
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