

Significance of Procedural Deficiencies on Aircraft Damage and Physical Injury in Aircraft Operation

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Abstract –Aviation is considered the safest mode of transportation. There has been an increase in incidents and accidents in the recent past. Incidents and accidents in the Aviation industry have caused severe damage to property and also human life. Many researchers have analyzed the effect of human error on aviation-related incidents and accidents. Analysis of data and literature reveals that adequate attention has not been given to procedural deficiencies in aviation-related incidents and accidents. Procedures play a vital role in the Aviation industry. Operators are expected to develop procedures for each, and every operation and the staff are expected to strictly follow them if the aviation industry is to achieve zero fatalities in commercial operations by 2030 and beyond.

Keywords: Aviation safety, Human factors, Procedural deficiencies

Nomenclature

CAA UK	Civil Aviation Authority United Kingdom
FAA US	Federal Aviation Administration United States
ICAO	International Civil Aviation Organization
ATC	Air Traffic Control
SARPs	Standard And Recommended Practices - ICAO
MRO	Maintenance Repair & Overhaul Organizations
MEDA	Maintenance Error Decision Aid
ASRS	Aviation Safety Reporting System
NTSB	National Transport Safety Board
AMT	Aircraft Maintenance Technician
SOPs	Standard Operating Procedures

1. INTRODUCTION

Although the perception that has been spread globally is that air transport is the safest mode of transportation, several recent incidents prompted us to reconsider that belief. Safety is of utmost importance from the beginning of the aviation industry. The Civil Aviation Authority (CAA UK) and Federal Aviation Administration (FAA US) have been established to regulate the aviation Industry. In addition to CAA UK and FAA US, the International Civil Aviation Organization (ICAO) was established in 1944 as a specialized agency of the United Nations to promulgate international standards. At present, 193 countries are members of the ICAO (Safety Report 2020ICAO).

According to the International Civil Aviation Organization (ICAO) Safety Report 2020 (Safety Report 2020ICAO), there has been a 16% increase in the total number of accidents from 2018 to 2019. For the year 2019, the accident rate per million departures is 2.9; whereas the rate in the year was 2.6. However, the good news is the reduction in the number of fatalities and fatal accidents. In the year 2019 there were six fatal accidents and 239 fatalities whereas in the year 2018, there had been eleven fatal accidents and 514 fatalities. However, the Global Aviation Safety Plan (GASP) is aiming to achieve a target of zero fatalities in commercial operations by 2030 and beyond (Safety Report ICAO 2020).

Some of these accidents have caused severe damage to aircraft, passengers, and other properties resulting in the deterioration of the industry's reputation, and also the economy of such countries. The cost incurred in an accident might be several million dollars.

Aviation safety mainly relies on aircraft operation, maintenance, and air traffic control which humans are handling. Also, the weather condition is a non-human contribution factor. In the aviation industry, all the above human handling factors have to be carried out in accordance with written-down procedures approved by regulatory authorities as obligated by ICAO standards and recommended practices (SARPs).

Bao and Ding (2014) have investigated a sample of 3783 ASRS incident reports submitted by maintenance and non-maintenance-related personnel. The authors have used Maintenance Error Decision Aid (MEDA) and Correspondence Analysis (CA) methods to analyze maintenance errors and their contributing factors and the relation between them. The research concluded that individual-related factors and management-related factors were the most frequent reasons for maintenance errors. From the maintenance personnel's perspective, individual-related factors lead to more maintenance errors. The authors highlighted in their report that the ASRS database could be a useful source of information.

Research carried out by Patankar (2002) to study the root causes of rule violations by aviation maintenance technicians, the data has been analyzed to establish the severity of the rule violation problems and to determine the most common violations and their associated sanctions. Secondly, self-reported errors documented by the Aviation Safety Reporting System (ASRS) have been analyzed to establish the general areas of vulnerability from organizational and individual perspectives in maintenance. Third, actual rule violation investigation reports provided by the industry partners have been analyzed to determine the root causes of these violations. The root causes were, again, classified in terms of organizational and individual factors. In conclusion, the report presented a reliable matrix of organizational and individual factors that need to be addressed in order to minimize rule violations due to maintenance errors.

Marais et.al. (2012) have investigated 769 NTSB accident reports, 3242 FAA incident reports, and 7478 FAA records of fines and other legal actions taken against airlines and associated organizations and quantifies maintenance contributions to airline accidents and incidents. In their study, the authors have identified main three pillars which have not been addressed adequately. The three pillars are:

1. What is the extent of maintenance's contribution to commercial passenger aviation risk, and what is the trend in this contribution?
2. How effective are the mechanisms used to ensure safety at reducing maintenance's contribution to aviation risk?
3. Are there opportunities for improving these mechanisms?

The authors analyzed data from National Transport Safety Board (NTSB) accident reports, Federal Aviation Administration incident reports and FAA records of fines and legal actions against airlines and associated Organizations under the enforcement actions.

Several risk matrices have been formulated and graphical interpretations were tabulated with respect to “maintenance” related accidents and incidents.

However, Karen and Matthew have addressed the first pillar only. Specifically, procedural errors have not been considered. However, the authors have stressed the importance of the procedures, and stated "the reliability and precision of Aircraft Maintenance Technician (AMT) is of no value if the procedures themselves are flawed". Finally, they have recommended increasing the level of investigation surrounding aviation incidents to reveal the root cause. Authors suspect that inadequate maintenance would be an important factor. However, the authors accept that "maintenance errors can occur when designing the overall maintenance plan or the individual procedures.

In the aircraft crash investigation reports, (system failure case studies, no left turns (2008)) the crash of “United Airlines Flight 232” reveals some of the procedural deficiencies that draw the attention of researchers. The United Airlines flight manual did not have a procedure for a complete hydraulic failure although a partial loss was considered. However, the Aircraft engine manufacturer also enhanced the manufacturing process and added the usage of ultrasonic detection of cracks in the order of 0.1 inches to the inspection procedures manual.

Flight 5481 which was a regularly scheduled passenger flight crashed shortly after takeoff from the runway On January 8, 2003, killing 21 people aboard including two crew members (Loss of Pitch Control During Takeoff Air Midwest Flight 5481 (2003). One of the primary reasons identified in this report is “Air Midwest’s maintenance procedures and documentation”.

Human factors, procedures, aircraft, company policy, weather, environment, airport, spare parts, Air Traffic Control (ATC), equipment, staffing, and so on were some of the many factors which were involved in aviation accidents and incidents.

Accidents and incidents due to the procedures may happen due to lacking or shortcomings or inadequate procedures, inappropriate procedures, non-compliance of the procedures, deviation of procedures, violation of procedures, etc., and so on. Aviation safety mainly relies on aircraft maintenance, operation, air traffic control, and ground handling which are handled by humans. The weather conditions also have a non-human contribution. In the aviation industry, all the above human handling factors have to be carried out in accordance with written-down procedures approved by regulatory authorities as an obligatory requirement by ICAO standards. In the aviation industry, most of the employees have to be authorized to work in different fields such as maintenance, aircraft pilot, air traffic control, cabin maintenance, cabin crew duties, etc. Once the employee is empowered, any deviation/violation of procedures is a punishable offense.

2. METHODOLOGY

Aviation is a very vast field. It involves commercial, non-commercial, general aviation operations, aircraft design & manufacturing, and component maintenance & overhaul, etc. Aviation safety relies on maintenance, operations, air traffic control, ground handling, cabin operation & maintenance, and so on. In all the above areas, procedural deficiencies may take place. This research concentrated only on the activities of regular commercial airline operations which impact the continuing airworthiness of commercial aircraft fleets.

Aircraft design & manufacturing organizations, Maintenance Repair & Overhaul (MRO) Organizations, and general aviation such as aerial work, training, private, charter, agriculture, etc., were not considered.

Further, the maintenance involved components that were removed from day-to-day line operations or aircraft design, and manufacturing organizations were also not taken into account.

The specific goal of this research was to study the procedural affectivity in regular commercial flight operations so that appropriate remedial actions, recommendations, and guidance materials for procedural development could be developed. Thereby errors due to procedural deficiencies in aviation could be prevented or minimized proactively.

At present globally, there are six main sources that maintain accident/incident report databases. National Aeronautics and Space Administration (NASA) USA which maintains the Aviation Safety Reporting System (ASRS), Bureau of Air Safety Investigation (BASI) Australia, National Transport Safety Board (NTSB) maintained by the Federal Aviation Administration (FAA) USA, The Aviation Safety Network (ASN) Safety Database, maintained by private, independent initiative founded in 1996 by flight safety foundation, ICAO Safety Accident/Incident database which is a restricted database and SKYbrary accident /incident database which was initiated by EUROCONTROL in partnership with ICAO, The Flight Safety Foundation, The UK Flight Safety Committee, and The European Strategic Safety Initiative are those sources. Since some databases were restricted and reports in some databases are very lengthy, taking into consideration time limitations and the availability of reliable data, the ASRS database was selected for this research study.

The ASRS receives incident reports from professionals involved in the aviation industry such as pilots, air traffic controllers, dispatchers, cabin crew, maintenance technicians, etc. (ASRS Program Briefing - Last Updated: December 2022). These reports are being sent to ASRS voluntarily describing unsafe and hazardous situations that they have observed. ASRS analyzes and processes such information and disseminates it to stakeholders.

One of the main purposes of disseminating such information is to identify deficiencies and discrepancies and provide data for planning and improvements for further improvement. By doing so, ASRS intends to improve and enhance the current aviation system with better adherence to human factor principles, development of better procedures in all sectors such as aircraft operations, facilities equipment, and maintenance, etc. not to reoccur such an unsafe situation. (SRS database ASRSDBOnline 2022). The ASRS database can filter databases and provide information to the reader. For this study, accident/incident reports available with ASRS (CAN1235346 ASRSDBOnline 2022) database have been used. These reports were on accidents/incidents that occurred from 1988 January to 2022 January. Based on the literature review, the authors have decided to analyze the most frequent contributors to aircraft damage and physical injury due to those accidents/incidents.

Contributing factors that have the highest impact in terms of frequency of involvement were selected and for each contributing factor, the extent of damage was quantified by identifying whether the aircraft was damaged and whether there was a physical injury to the passengers involved in the accidents/incidents.

3. ANALYSIS

For the analysis, a total of nine contributing factors with the highest occurrence of incidents related to aircraft Damage and causing physical injury to the passengers have been selected. The total frequency of involvement for each contributing factor, the incidents involving aircraft damage, and the occurrence of physical injury gathered from ASRS reports are given in Table 1.

Table 1 shows the frequency of involvement of each Contributing factor in selected accidents/incidents from 1998 to 2022. The highest contributing factor was Human factors which is 67% of the total number of factors that have been listed in Table 1. The second highest is Aircraft, accounting for 26% and procedural deficiencies come to the third position with 4.75%. Past research has been done on the contribution of Human factors and aircraft to incidents and accidents (Bao.M and Ding.S,(2014)). However, during the literature review, the authors have not been able to find research pertaining to the procedural deficiencies for accidents and incidents, therefore, the authors are of the view that prominent importance has to be given to procedural deficiencies.

Table 1 Summary of selected incident/accident reports from January-1988 to February-2022

Contributing factor	Frequency of involvement	Aircraft Damaged	Physical injury to passengers
Aircraft	44279	3750	508
Environment - non weather related	2593	383	142
Equipment tooling	474	32	27
Human factors	114063	6601	649
Logbook Entry	37	0	0
Manuals	347	9	0
MEL	230	7	0
Procedure	8098	170	48
Software and automation	38	0	0

Further, the contribution of each factor to aircraft damage and the contribution of each factor to physical injury to the passengers was also analyzed. The occurrence of each result in terms of aircraft damage and injury was analyzed against each contributing factor in Table 1. The analysis revealed that out of all human factors-related accidents/incidents, 6601 incidents which is 5.78% out of the total of 114063 have caused damage to the aircraft. The aircraft as a contributing factor has caused damage to the aircraft 3750 times out of 44279 which is 8.4%. The environmental conditions occupy 14.7% whereas the procedural deficiencies have contributed to 170 damages to aircraft accounting for 2%.

The analysis of each incident/accident category on physical injury also reveals that human factors contributed to 649 physical injuries accounting for 0.56% out of all reported human factor-related accidents/incidents. However, procedural deficiencies also contributed to 48 injury-related incidents which is 0.6% of all procedural deficiency-related incidents/accidents.

The above analysis reveals that human factors, aircraft, procedural deficiencies, environment, and aircraft are major contributing factors to aircraft-related accidents/incidents. However, the literature review revealed that previous researchers

have not paid much attention to procedural deficiencies as a major factor that needs the attention of aircraft operators and government authorities.

Further analysis of incident/accident reports, the authors have been able to reveal deficiency categories given in Table 2 as major contributors to procedural deficiencies.

4. RESULTS

Incident/accident reports have been analyzed to identify major deficiencies category-wise. The result showed that there were some deficiencies when procedures were developing. Below were some of them which have been identified by the researchers by ASRS report review.

Improper Phraseology

Effective and clear communication is important for incident/accident-free safe aviation. Differences in languages might increase room for misunderstanding and error. Improper phraseology that is being used in different parts of the world has caused accidents/incidents. The ASRS report no 1235346 (2022) reports “Improper, or non-standard phraseology during the assignment of Go around/missed approach”. The controller didn’t use go around or discontinue approach phraseology.

Not clear or ambiguous

When developing procedures, the operator has to prepare very clear step procedures to follow within the time allocated. Otherwise, the work floor staff will be in trouble, and they will try to bypass or violate them since staff need to complete the work within the scheduled time. The ASRS report CAN 1198919 (2022) reports confusion in procedures. ACN: 1206729 has reported a confusing book and the non-availability of a procedure for a complex operation.

Inappropriate procedures

This was also a defect in the preparation of the procedures. A procedures development process has to be followed to rectify these defects or deficiencies and also in the process of preparation of procedure, the industry has to use the people who know the subject area well ACN: 1226560 (2022) and ACN1434509 (2022).

Referring to some other procedures make confessions

In some procedures, there are a number of other procedures to be referred to. It will be a problem for the work floor staff to find out the other referenced materials within the limited time frame. The ACN 1439855 (2022) refers to a procedure that was necessary to refer to some other procedure.

Complex/complicated procedures

Sometimes complex or complicated procedures are available. So, people will tend to bypass or ignore the procedures. Also, the time will take to get these tasks clear in those instances. ASRS REPORT numbers ACN: 1233858 (2022) and ACN: 1216908 (2022) are related to complex procedures and further propose to discuss the procedure with the users so that incidents could be avoided in the future.

5. DISCUSSION

This study analyzed the procedural deficiencies in the commercial aviation industry by studying ASRS reports submitted by both maintenance personnel and non-maintenance personnel.

The result showed that human factor error and procedural deficiencies accounted for a large proportion of accidents and incidents while aircraft defects also had a considerable contribution.

The procedures themselves had a number of deficiencies which led to non-attendance to procedures such as some procedures were not clear or ambiguous, inappropriate procedures, referring to some other procedures make confusion, procedures were more restrictive, use of shortcuts due to very lengthy procedures, inappropriate, Incomplete, nonstandard, not having adequate data, having unacceptable data, Rewording necessary and very complex procedures, etc.

In the aviation industry, there has been a 16% increase in the total number of accidents from 2018 to 2019. From 2018 to 2019, there had been a 12% increase in accidents per million departures. However, a reduction in the number of fatalities and a number of fatal accidents has been observed during the period from 2018 to 2019.

Many researchers have analyzed the reasons for accidents and incidents in aviation. However, significant attention has not been given to the procedural deficiency aspect although some of them have not totally ignored the fact that procedural deficiencies also can play a major role.

The highest contributing factor was Human factors which is 67% the second highest is Aircraft, accounting for 26% and procedural deficiencies come to the third position with 4.75% if considered as the primary factor. However, if considered as a secondary or tertiary contributing factor, this percentage will increase further. The authors would like to quote ASN Numbers ACN: 1838870, 1838807, 1817740, 1813994, 1810675, 1802425, 1784065, and 1757535 as examples where the primary cause was either a human factor or aircraft whereas procedure was identified as a secondary factor.

According to analysis, the procedural deficiencies have contributed to 170 damages to aircraft accounting for 2%. Further, having analyzed the ASRS database, major contributing factors for deficiencies have been identified.

6. CONCLUSION

The analysis of results revealed that the procedure factor is one of the most significant primary factors prone to an aviation accident or incident which may lead to major disasters. Procedures are the backbone of maintenance and operation in the aviation industry. This is one of the most important factors in maintaining flight safety during maintenance and operations which should be proactively looked into. Proactive rather than reactive safety programs are particularly important, considering the high social and economic costs of airline accidents. Encouraging 'best practice' by proactively identifying safety deficiencies before they made damage will ultimately improve airline safety performance and reduces damages to the passengers, aircraft and also losses to the industry and subsequently to the economy. This is further reiterated with the intention of GASP to achieve zero fatalities in commercial operations by 2030 and beyond. If this target is to be achieved, serious attention has to be drawn to all possible aspects that may contribute to a fatality.

If GASP is to achieve long-term plans projected for the future, the authors propose to develop a manual on the development of procedures taking into consideration the deficiencies analyzed in the research literature.

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