Human Factors Analysis for Aviation Accidents and Incidents in Singapore

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Abstract. The aviation industry is an important sector in contributing to a nation's economy and its growth and development. The continuous improvement in the aviation industry with the adoption of new technology has developed trust and confidence amongst people all over the world. However even with such improvement and technological advances embedded in the aviation industry, accidents still cannot be avoided. An aviation accident is characterized as an incident that is directly related to an aircraft's service. Aviation accidents are often the result of a number of causes and contributory factors, many of which have a human dimension to them. In some cases, human error is a factor in as high as 70% of aircraft accidents (Feggetter 2007). Hence, the challenge for accident investigators is how best to identify and mitigate the causal sequence of events leading up to an accident. The Human Factors Analysis and Classification System (HFACS) is a general human error framework originally developed and tested within the USA military as a tool for investigating and analysing human causes of aviation accidents (Li et al. 2008). The applicability of HFACS to the analysis of large-scale datasets of incidents and accidents has also been demonstrated in both civil and military aviation environments in Taiwan, India and Australia. Further, this framework has been extended and adapted to analyse the underlying human factors causes in accidents involving remotely piloted aircraft, aviation maintenance and railroad accidents. In Asia, Singapore has a strong and robust economy and operates one of the world's most successful and recognisable airlines. It is therefore surprising that little is known about human error in the aviation context. Thus, one purpose of the present study is to assess the utility of the HFACS framework as an error analysis and classification tool for accidents/incidents in the aviation industry in Singapore. Specifically, HFACS will be applied to commercial aviation accident and incident records maintained by the Transportation Safety Investigation Bureau (TSIB) of the Ministry of Transport (MOT). The TSIB is the air, marine and rail accidents and incidents investigation authority in Singapore. Its mission is to promote transport safety through the conduct of independent investigations into air, marine and rail accidents and incidents. A comprehensive review of 75 accidents and incidents that occurred between October 2000 and December 2019 in Singapore has just been undertaken. This is currently being analysed within a HFACS context and the findings will be reported here. Thus, the utility of the HFACS framework will be appraised, an overview of the 75 accidents will be given, and more specific detail relating to human error will be reported. At a later stage, these findings will be compared with other countries in Asia where similar data is available. Researchers claim that the HFACS framework bridges the gap between theory and practice by

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providing safety professionals with a theoretical tool for identifying and classifying human errors in aviation mishaps (Wiegmann and Shappell 2001a, b, c). The system focuses on both latent and active failures and their interrelationships, thereby facilitating the identification of the underlying causes of human error. The findings from this research will allow safety managers, administrators and other aviation professionals working in airlines, airports and aviation regulatory organizations to analyse their safety programmes' strengths and weaknesses. This will also contribute to the build-up of a comprehensive database in Southeast Asia. Finally, this study is unprecedented in Singapore and will offer new insights into the nature and trends of human factors in aircraft accidents and incidents.

Keywords: Human factors · HFACS · Aviation safety · Accidents and incidents · Air traffic

1 Introduction

The growth of the aviation industry has made air transport to be one of the fastest modes of public transport across international boundaries. It has provided profits for many airlines and has contributed towards the improvement of the world economy. An airline's profitability contributes towards the strong economy of a country. The sustainability and growth of the aviation industry involves the prerequisites of safety as an important consideration for the public. Hence, aviation safety has been considered as an important aspect for the healthy development of the aviation industry. The conditions during the second half of the 20th century have changed the perception of the aviation industry and the technical issues turned out to be human error issues that have affected aviation organizations and their safety environment (Zhou et al. 2018). Hence, it has been revealed that human errors have been considered as one of the most frequent errors that lead to aviation accidents (Wiegmann and Shappell 2016). Human error has been mostly found prevalent in almost all the aviation accidents, but still no prevention programs have been designed for reducing the occurrence of such errors.

It is clearly revealed that almost 70–80% of all the aviation accidents have occurred due to human errors (Gong et al. 2014). Human errors resulting in aviation accidents have been considered to be the major concern in aviation industries across the world (Salmon et al. 2012). The International Civil Aviation Organization (ICAO) has stated previously that aviation is arguably the safest mode of mass transportation across international boundaries. The shift of the aviation industry from having a fragile safety record to becoming the first ultra-safe system is due to the incessant investment in safety efforts by the aviation community (Yeun et al. 2014). Even after such advancements in aeronautical technology and weather forecasting, aviation accidents still cannot be eliminated. Aircraft accidents arise due to human errors, loss of control, mechanical failure or bad weather (Li et al. 2015).

The airlines work to provide the best flying experience to their passengers concerning their safety, comfort, punctuality and hospitality. These services onboard are carried out by the cabin crews and pilots who are responsible for looking after their passenger's needs. Hence, appropriate training programmes are provided to the aircrew members for maintaining the safety during the air operations and reducing the impact of any type of errors (Vatankhah 2021).

The Human Factors Analysis Classification System (HFACS) based on the 'Swiss-Cheese' model (Resaon 1990) consists of a human error framework that has been mainly used for analysing the human error accidents in the American military aviation operations and the developers of this frameworks have represented its applicability for commercial and general aviation accident analysis (Wiegmann and Shappell 2001a, b, c; Shappell and Wiegmann 2003). Human factors are considered important for understanding human performance and have been mainly used in the investigation of maritime and railway accidents that occur due to human errors (Reinach and Viale 2006; Baysari et al. 2009; Vairo et al. 2017).

Aviation is a major driver in Singapore's economy. The Singapore aviation sector contributes to about 3% of the country's Gross Domestic Product (GDP) and plays an indispensable role enabling other sectors such as tourism, financial services, retail and manufacturing[1]. Singapore is also an air transport hub of the region with the 9th busiest airport in Asia[2] as well as an established aerospace maintenance, repair and overhaul (MRO) sector.

To support Singapore's airports, airlines and other support facilities, the air transportation sector employs about 119,000[3] people in diverse roles such as flight crew, air traffic controller, ground services personnel, engineers, technicians, etc. The focus of this study will be on the flight crew operating aircraft in Singapore Airspace.

2 Aims and Objectives

This section will elucidate aim and formulate objectives to achieve the identified goals. The study will be backed by the following objectives:

1. To assess the utility of the HFACS framework as an error analysis and classification tool for accidents/incidents in the aviation industry in Singapore.
2. To identify the unsafe acts and human errors in aviation concerning the accidents/incidents in Singapore.
3. To analyze HFACS framework towards implementation of operation safety in aviation in Singapore for preventing the serious consequences of aviation accidents/incidents.

3 Literature Review

3.1 Major Aspects of Aviation Accidents

The complexity of the human factors has been considered as the major cause of occurrence of aviation accidents. Different models have been formed for analysing and investigating the human factors responsible for causing aviation accidents so that the number of

[1] https://www.caas.gov.sg/public-passengers/learn-about-singapore-aviation.

[2] https://edition.cnn.com/travel/article/asia-busiest-airports-2019/index.html.

[3] https://www.iata.org/en/iata-repository/publications/economic-reports/singapore-value-of-aviation/.

such incidents are reduced and prevented (Shappell et al. 2007). Different surveys have been conducted on aviation accidents and incidents for the awareness of air transportation safety (Helmreich and Merritt 2017). Despite progress and awareness concerning these accidents, the cases of air accidents have not reduced significantly.

Aviation accidents are considered as the events occurring due to non-functionality of the operations in the aircraft from the time of boarding of the passengers till the landing of the flights where all the passengers have disembarked (Abeyratne 2012). It also constitutes any operational defect during this time that involves fatal or heavy injury of individuals, damage or loss of the aircraft. Aviation incidents involve the fluctuations in the operational activities of the aircraft that could affect the safety of the passengers. Aviation incidents are mostly represented in the form of faulty actions of the individuals or inappropriate operations related to airborne and ground-based equipment that supports the consequences of the air operations that results in the termination of flight and non-performance of emergency protocols (Clothier and Walker 2015). The major causes of aviation accidents and incidents involve various factors. The major factors involve human errors along with some technical and meteorological factors. The outcomes of poor adherence towards the organization of legislative procedures and the mismanagement of air operations have been the major cause for the occurrence of aviation accidents.

3.2 Human Errors and Unsafe Acts in Aviation Accidents

Human errors and unsafe activities have been considered as the major issues that contribute towards aviation accidents and incidents (Chen and Vincent 2018). The causes of human errors include the errors made by pilots, maintenance engineers, air traffic controllers and related professionals who have a direct impact on flight safety. The failure towards maintaining the operational and organizational activities by the related professionals in aviation contributes towards the occurrence of aviation accidents and incidents by the humans (Reason and Hobbs 2017). Adverse weather conditions contribute towards air accidents in many different ways. The weather conditions are not always found to be appropriate but the information given to the flight crews during the take-off and landing cannot change accordingly (Ji et al. 2011). The decisions of the flight crew are completely dependent upon the information being available to them. No practical need has been made mandatory for the separation of environment from operational factors. The inadequate information provided to the crew members of the flight leads to the lack of critical data collection which in turn leads inappropriate decisions that cause air accidents. In some cases, it has been analysed that the crew members of particular flights have necessary data that are required but often these data are misinterpreted by them (Kelly and Efthymiou 2019). In some cases, it has been analysed that the crew members of particular flights have necessary data that are required but often these data are misinterpreted by them (Oliver et al. 2019). Sometimes even though the flight crew have all the necessary data and are able to interpret the data appropriately, their insufficient skills training and related protocols for taking appropriate decisions to be carried out at particular time is missed upon. This leads to a lack of situational awareness that in turn causes aviation accidents and incidents (Flin and Maran 2015). Increased workload of the crew members has caused deterioration in the operational activities of the flight.

Unsafe acts in the aviation industry have often led towards the occurrence of accidents and incidents (Wiegmann et al. 2005). Unsafe acts have been categorized as errors and violations. Errors are unintentional behaviours and violations are disagreements with rules and regulations (Chen et al. 2017). Skill based errors occur during operational execution that involves practice of the tasks concerning the protocol, training and any alteration in such operational activities results in unsafe situations. Decision errors are another type of unsafe acts which involves the behavioural and actional changes in the operational proceedings which evolves inappropriate decision making that results into unsafe situations (Wagener and Ison 2014). Perceptual errors occur when a person's perception of the situation differs from reality because of faulty information gained from the other sensory units. The unsafe acts in the aviation industry are also brought about by environmental factors, operational conditions and personnel factors (Reason 2008). The physical environment consisting of weather conditions and the technological environment consisting of variations in the designs and automation issues resulting into inappropriate maintenance of the aircraft are also causal factors (Erjavac et al. 2018). The mental state of the flight crew operating the aircraft and their physiological conditions also affects the performance on the flight. Personnel factors involve the management of the crew members of the flight involving their communications, planning, coordination and teamwork issues (Shappell et al. 2007). The inappropriate supervision of the flight crew with the lack of guidance, training, and leadership results in unsafe activities that may cause the air incidents and occurrences (Ancel and Shih 2012). Organizational influences due to the inappropriate organizational climate, lack of operational process and lack of resource management have also contributed to the unsafe acts (Li and Harris 2006).

3.3 Human Factors Analysis and Classification System (HFACS)

The Human Factors Analysis and Classification System (HFACS) has been considered as a systematic framework for analysing accident analysis. It involves the analysis of the various accidents and incidents taking place, mainly due to the human errors. This framework consists of analysing data related to the accidents in the well-structured form. The Human Factors Analysis and Classification System (HFACS) framework established by Wiegmann and Shappell (2001a, b, c) has proven to be a reliable tool in accommodating human causal factors associated with aircraft accidents. Based upon Reason's (1990) model of latent and active failures, HFACS addresses human error at all levels of the aviation system, including the condition of aircrew and organizational factors (Wiegmann and Shappell 2001a, b, c). There are four levels of HFACS. These are: level 1 (unsafe act of pilots or operators), level 2 (preconditions for unsafe acts), level 3 (unsafe supervision) and level 4 (organizational influences). Level 1 (unsafe acts of operators - active failures) is the level at which the majority of accident investigations have been focused in the past. These are the behaviours of the flight crew on the flight deck that contribute directly to the accident. Level 2 (preconditions for unsafe acts - latent/active failures) addresses the psychological precursors to the active failures at level 1. Level 3 (unsafe supervision - latent failures) traces the causal chain of events producing the unsafe acts up to the level of the front-line supervisors. Level 4 (organizational influences - latent failures) describes the contributions of fallible decisions in upper levels of management that directly affect supervisory practices, as well as the conditions and actions of front-line operators (Harris et al. 2007). Hence, the researchers are able to obtain the data related to the accidents from this framework for efficient analysis. HFACS was developed for the US naval aviation for analysing the aspects of human factors in accidents. It is basically known as a generic human error-coding framework. The development of HFACS has been implicated in several papers and books (Weigmann and Shappell 1997, 2001a, b, c, 2016; Shappell and Wiegmann 2001, 2003, 2004). This framework is based and derived from Reason's model of accident causation. Reason's model involves the active and latent failures that combine together along with other factors for coping up with the defences of the system (Reason 1990). The active failures involve the errors related to the performance of operators in the complex system and the latent failures involve the distal errors and system misspecifications, which lie dormant within the system for a long time. The fact was revealed that the complex system types are managed and maintained by human beings and therefore the human decisions and actions need to be implicated in all accidents. The latent failures are spawned in the upper levels of the organization and are related to its management and regulatory structures. Reason's model has been known to be influential in terms of human errors in aviation accidents. This model was not capable of providing remedial solutions towards aviation related accidents. Hence, based on this model, the HFACS framework has been developed in order to fulfil such types of needs (Shappell and Wiegmann 2003). The HFACS framework has shown efficacy in the analysis of accidents in the US commercial aviation, US general aviation and Australian general aviation (Wiegmann and Shappell 2001a, b; Shappell et al. 2007; Shappell and Wiegmann 2003, 2004; Lenné et al. 2008).

HFACS has been considered important for analysing the causes of accidents and is efficient in the identification of the related risk factors of the accidents. Figure 1 represents an overview of the HFACS. This framework has been proved to be an effective tool in identification of human errors in various domains such as railways, mining, etc. (Baysari et al. 2009; Patterson and Shappell 2010; Chauvin et al. 2013). This framework has been found to be efficient in analyzing the General Aviation accident data by the insurance companies (Lemeé 2006). It has also been used in the process of the prospective assessment concerning the effectiveness of aviation safety products that has been developed by NASA aviation safety programmes (Andres et al. 2005; Lechner and Luxhoj 2005; Luxhoj and Hadjimichael 2006).

3.4 Operational Safety by Utilizing HFACS Framework in Aviation

Human errors have been considered as one of the most frequent threats towards safety of lives in aviation (Harris and Li 2010). These errors have been responsible for the creation of failure in the complex systems which have been managed, operated, designed and maintained by the humans (Plant and Stanton 2012). Hence, the decision-making of human beings and their actions at the organizational level are implicated in all types of accidents (Reason 1997). The Human Factors Analysis and Classification System (HFACS) has helped in identifying the human errors for maintaining the operational safety in the aircraft and preventing air accidents and incidents. Many studies have been conducted using the HFACS framework for maintaining the operational safety in aviation. One of the studies involving aircraft registered in Taiwan has been analysed for

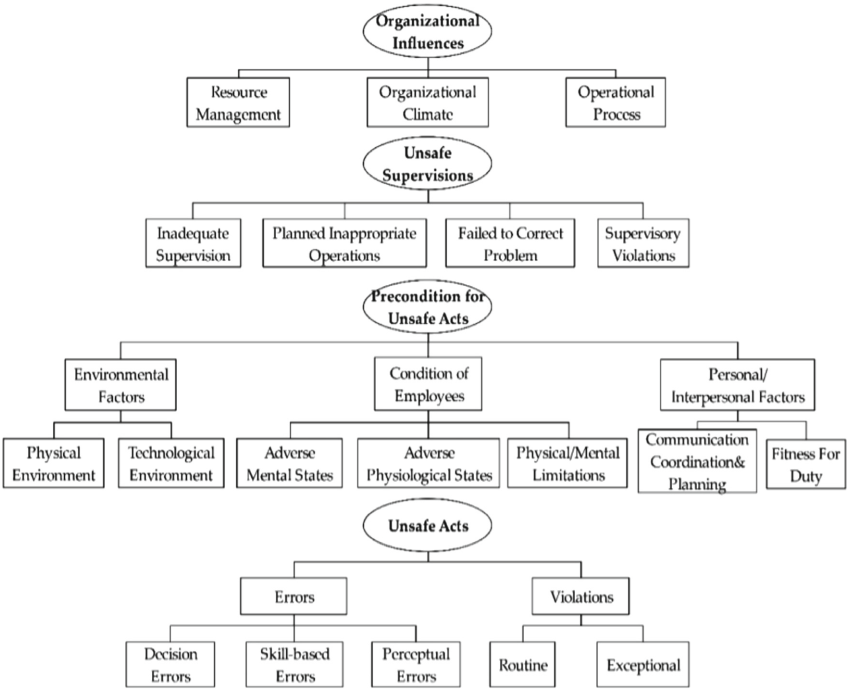

Fig. 1. Overview of human factors analysis and classification system (HFACS)

41 aviation accidents. This study revealed that errors at operational levels are associated with organizational inadequacies. Hence, the findings from this study have evolved the direction for utilizing human error intervention strategy involving remedial safety actions which are aimed at high organizational areas (Li and Harris 2013). Also, the framework has been efficient in analysing the influential factors of violation behaviour that revealed that the attitude of the management may influence the operator's attitude along with their groups, norms, work pressure and behaviour (Fogarty and Shaw 2010).

Safety has been the major priority in the aviation industry and hence safety management systems have been developed by the commercial airlines for reducing the occurrence of hazardous factors in aircraft operations (Liou et al. 2008). Various applications of HFACS in aviation have been studied for identifying the human errors and reducing the aviation accidents. The utilization of HFACS has helped in analysing the human factors caused in accidents involving remotely piloted aircrafts too (Tvaryanas et al. 2006). Maintenances error in the aircraft have been analysed by the adaptation of the HFACS-ME (Krulak 2004). Another study has shown the utilization of the HFACS framework in identifying the human factors in the Asiana Airlines flight 214 accident that occurred on July 6, 2013 (Small 2020). The result of this study has revealed that inappropriate training of the pilots, lack of supervision and deviations from the standard operating procedures (SOPs) were the major issues that contribute towards air accidents. Hence, the HFACS framework helps in identifying errors and implicates the practice of safety measures for reducing the impact of such accidents. The HFACS framework has also shown efficiency in analysing the human errors for Airport surface deviations and runway incursions. For example, the loss of situational awareness has deviated the pilots and air traffic controller's attention leading towards runway incursions (Torres et al. 2011). These situations have been mitigated by training the pilots and the related professionals so that awareness and attentiveness is maintained. Hence, the operational activities need to be strictly maintained for reducing the aviation accidents and maintaining the safety of the aircraft. Tools and techniques have been evolved for mitigating such impact of air accidents so that prior symptoms of such accidents are addressed and immediate solutions are implicated concerning the same.

4 Research Methodology

4.1 Description of the Study Area

The study encompasses civil aircraft flights to and from Singapore's two commercial airports – Singapore Changi Airport and Seletar Airport. As a major international air hub, Changi Airport in 2019 handled about 382,000 commercial aircraft movements comprising both passenger flights and air freights[4]. The flights to and from Changi Airport are operated by a myriad of Full-Service Carriers (FSCs) as well as Low Cost Carriers (LCCs).

Seletar Airport is primarily a general aviation airport although Firefly Airlines, an LCC based in Malaysia, operates its ATR72 aircraft there as well. Other than the Firefly Airlines flights, Seletar Airport also oversees chartered flights, private aircraft and training flights. There are three flight schools in Seletar airport that operate general aviation aircraft such as the DA40 and Cessna 172.

A comprehensive review of all 75 Air Safety Investigation Reports between October 2000 and September 2019 was carried using database records maintained by the Air Accident Investigation Bureau of the Ministry of Transport in Singapore. Of particular interest in this study were those accidents and incidents attributable, at least in part to the aircrew operating the flights. Accidents due solely to catastrophic failure, maintenance errors and unavoidable weather conditions such as turbulence and wind shear were not included. Furthermore, only those accidents and incidents in which the investigation was completed, and the cause of the occurrence determined were included in this analysis. On the whole 48 reports related to aircrew related human factors occurrences met these criteria. The type of aircraft operations involved in this study were commercial passenger aircraft, commercial cargo and general aviation. The total number of accidents analyzed were 22 and the number of incidents were 53.

4.2 Research Design

In accordance with the research query and objectives, the study aims at addressing, a descriptive research design**.** Descriptive research design facilitates explaining the events as they independently occur in nature without any interference or manipulation of data from the researcher. Additionally, it will help in justifying the results of the study in a strategic manner.

[4] https://www.changiairport.com/corporate/our-expertise/air-hub/traffic-statistics.html.

4.3 Research Paradigm

The current study will utilize an interpretivism research paradigm as it aims for assessing the utility of the HFACS framework as an error analysis and classification tool for accidents/incidents in the aviation industry in Singapore. This research paradigm has been implemented when the objectives are directed towards outlining issues and measures of social issues of aviation accidents and incidents which has been found to be prevalent due to human errors.

4.4 Research Approach

The present research study aims to assess the utility of the HFACS framework as an error analysis and classification tool for accidents/incidents in the aviation industry in Singapore. The study adopts a qualitative research approach since the researcher collects data through a comprehensive review of accidents and incidents that occurred in Singapore. The HFACS framework has been applied to commercial aviation accident and incident records maintained by the Transportation Safety Investigation Bureau (TSIB) of the Ministry of Transport (MOT). The TSIB is the air, marine and rail accidents and incidents investigation authority in Singapore which is further used in this study to achieve the aims and objective of the paper. Its mission is to promote transport safety through the conduct of independent investigations into air, marine and rail accidents and incidents. Therefore, the current study utilizes a quantitative research approach. This can be attributed to the fact that interpretivism philosophy is most appropriate to implement with a quantitative approach. Moreover, it has helped in accumulating objective data through a wider sample size.

4.5 Data Analysis

The secondary data involves the comprehensive review of accidents and incidents that occurred in Singapore that needs to be analysed. This collected data is being analysed within the HFACS context. Thus, the utility of the HFACS framework has been appraised for reviewing such accidents and more specific detail relating to human error can be reported accordingly. In a later study these analyses will be compared with data from countries in Asia where similar databases and accident investigation reports are available.

5 Results and Discussion

The HFACS framework bridges the gap between theory and practice by providing safety professionals with a theoretical tool for identifying and classifying human errors in aviation mishaps (Shappell and Wiegmann 2001). The HFACS framework can be used to reliably identify underlying human factors problems associated with the 75 accidents and incidents recorded in Singapore. The HFACS framework has addressed four major types of human errors. Level 1 consists of unsafe acts of operators. Errors and violations are classified at Level 1. Level 2 consists of preconditions for unsafe acts involving latent and active failures. This level has described substandard conditions of operators and their substandard practices. Level 3 consists of unsafe supervision with latent failures traced in the causal chain of events evolving unsafe acts up to the level of the front-line supervisors. Level 4 consists of an organizational influence that describes the decision-making in upper levels of management while supervising the practices.

Although there were 48 flight occurrences associated with aircrew human factors, a total of 76 causal factors were observed and analysed using the HFACS framework. Instances of all but two HFACS categories (i.e. adverse physiological states and personnel readiness) were observed at least once in the database. Refer to Table 1 and Fig. 2 below for a summary of the HFACS factors observed.

Table 1. Summary of observed HFACS factors

HFACS factors	Total numbers	Percentage
Organizational Influences: Resource Management	4	5.3
Organizational Influences: Organizational Climate	2	2.6
Organizational Influences: Organizational Process	6	7.9
Unsafe Supervision: Inadequate Supervision	5	6.6
Unsafe Supervision: Planned Inappropriate Operations	1	1.3
Unsafe Supervision: Failed to Correct Problem	1	1.3
Unsafe Supervision: Supervisory Violation	1	1.3
Precondition for Unsafe Acts: Adverse Mental States	1	1.3
Precondition for Unsafe Acts: Adverse Physiological States	0	0.0
Precondition for Unsafe Acts: Physical/Mental Limitations	1	1.3
Precondition for Unsafe Acts: Crew Resource Mismanagement	7	9.2
Precondition for Unsafe Acts: Personal Readiness	0	0.0
Unsafe Acts: Decision Errors	13	17.1
Unsafe Acts: Skill-based Errors	20	26.3
Unsafe Acts: Perceptual Errors	8	10.5
Unsafe Acts: Routine Violations	1	1.3
Unsafe Acts: Exceptional Violations	5	6.6
Total	**76**	**100**

At the unsafe act level, skill-based errors were associated with the largest percentage of occurrences. Approximately 26% of all aircrew related accidents were associated with at least one skill-based error. The proportion of incidents and accidents has remained relatively unchanged over a 19-year period in the study. Notably the highest proportion of accidents and incidents associated with skill-based errors occurred in the year 2013. Among the remaining categories of unsafe acts, accidents and incidents associated with decision-based errors contributed the next highest proportion (i.e. 17% of the accidents

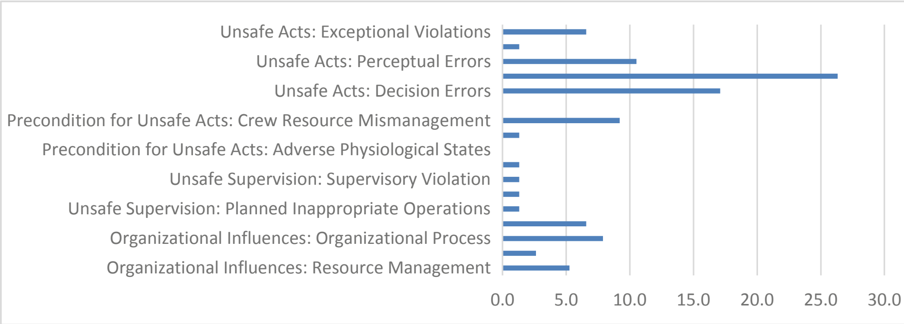

Fig. 2. Comparison of observed HFACS factors in percentage

and incidents examined). The proportion of incidents/accidents associated with decision-based errors remained relatively constant throughout the years of study. Perceptual errors contributed about 10% of the occurrences examined. The number of perceptual errors remained relatively constant throughout the period of study. Occurrences attributable to violations of rules and regulations numbered about 8%.

Within the pre-conditions level, Crew Resource Management (CRM) failures were associated with the largest percentage of occurrences. Approximately 11% of all aircrew related incidents and accidents were associated with at least one CRM failure. However, the percentage of occurrences associated CRM failures remained relatively constant over the 19-year period of the study. There was one incident each of adverse mental state and physical/mental limitation. There were no occurrences associated with personal readiness issues or adverse physiological states.

Compared to the category of unsafe acts, the number of AAIB reports that implicated the aircrew as contributing to an accident or an incident citing some form of supervisor and organizational factor was comparatively smaller. There were 10% of the occurrences that involved some form of supervisory influence and about 16% of occurrences that implicated organizational factors.

A trend analysis was done to compare the number of human factors related accidents and incidents, and the overall aircraft movements in Singapore from 2000 to 2019. Refer to Fig. 3 below. Since 2000, the human factors related occurrences are on an overall rising trend although the numbers have remained fairly constant since 2013. Incidentally, 2013 also registered the peak in the number of occurrences. The overall increase in accidents and incidents can be attributed to the rise in aircraft movements in Singapore, which saw a 120% jump from 2000 to 2019.

In summary, the HFACS framework was found to accommodate all 76 causal factors associated with 48 accidents in which pilots were involved across a 19-year period in the Singapore aviation industry. The error categories that were originally developed for military aviation in the United States are applicable within the commercial aviation space in Singapore. There were two errors factors within the HFACS framework that were never observed in the Singapore AAIB data base. For example, there were no instances in which crew personal readiness and adverse physiological states were causal factors. Unsafe acts in total contributed approximately 62% of occurrences related to

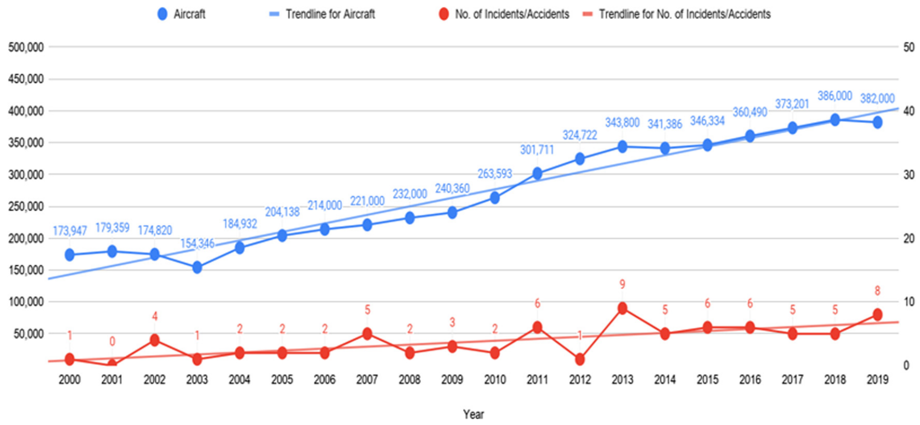

Fig. 3. Comparison of human factors related accidents and incidents, and aircraft movements: 2000 to 2019.

flight operations. The next highest category was organizational influences which was 16%, followed by pre-conditions for unsafe acts at 12%. Finally, the proportion of accidents and incidents associated by unsafe supervisions was 10%.

HFACS was utilized in analysing accident databases done other countries, like India, USA, Africa and Australia (Gaur 2005, Munene 2016, Inglis and McRandle 2007) and it was shown to accommodate all human factors that contributed to aircraft accidents.

6 Significance of the Study

The present study has analysed the identification of human errors which is responsible for causing aviation accidents and incidents in Singapore. The present study has utilized the HFACS framework in identifying the human errors and this could help in prevention of any incidents and accidents. Using this framework aviation organizations will be capable of identifying the weak links which are the causes for the occurrence of aviation accidents. The study has shown efficacy in identifying human performance and reducing the system deficiencies for maintaining safety measures in the aviation industry. The HFACS framework helps in analysing the weak areas that will help in reducing the accident and injury rates. Also, this study has provided a direction towards analysing and reviewing historical accidents and adoption of safety measures for avoiding the possibilities of such accidents. Hence, this framework has been used as an important assessment tool towards the guidance of future investigations and helps in improving the quality and accessibility of human factors that are prone for the occurrence of accidents and incidents. The significance of the study will be increased by comparisons with aircraft accident and incident data in other countries. Comparison of the results of this study against another country's similar study will assist in the interpretation of types of causal factors leading to incidents and accidents in Singapore. It will help clarify strengths and weaknesses in the Singapore aviation system.

7 Conclusion and Recommendation

The present study has aimed at assessing the utility of the HFACS framework as an error analysis and classification tool for accidents/incidents in the aviation industry in Singapore. The analysed accidents and incidents that occurred between October 2000 and December 2019 in Singapore have been undertaken with more specific detail relating to human errors. The different categories of unsafe acts in the HFACS framework have helped in analysing the identification of these errors which can be further used for preventing other possible air accidents and incidents. This framework can be used in other data sets as well as for establishing the relationship of errors with the accidents and incidents in supporting the HFACS framework to be an effective tool in analysing human errors. This study provides an understanding, based on the evidence of how actions and decisions at different levels in the organization facilitates aircraft operations resulting in operational errors and accidents. The present study can also contribute in building up the comprehensive database in Southeast Asia. This study can offer new insights into the nature and trends of human factors in aircraft accidents and incidents.

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