Review paper

UNDERSTANDING HUMAN ERROR IN AVIATION

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Abstract: *Error is an integral part of human performance, resulting from physiological and psychological limitations inherent in humans. It has been a contributing factor to the majority of incidents and accidents in any field of human activity. Approximately 80% of aviation events are caused by a decrease in human performance. As aviation safety depends on minimising error in all constituents of this compound system, it is primarily important to classify errors in order to better understand their nature and causes, and investigate them. A holistic approach to error also needs to be taken for its investigation and analysis, since humans do not act in isolation.*

Human performance is a complex process, influenced by work environment, technology, various cultural aspects and other participants in it. A mismatch in interaction of humans and other components in this process leads to error, and therefore it must be scrutinised in all facets of the aviation system. While errors resulting in incidents, accidents and loss of life are mostly made by pilots or air traffic controllers and draw more attention, those made by maintenance staff also need to be taken seriously, since they can result in fatalities and damage to aircraft as well, and entail significant consequences to air traffic. The aim of comprehending why people make errors is to elaborate safety recommendations and technological solutions that will decrease the likelihood of aviation events, and mitigate the consequences.

Errors can be managed and reduced primarily by creating an error-tolerant environment rather than punitive environment, improving error training, and using a number of technological models, aids and methods, including the threat and error management concept. Human error cannot be eliminated, but by understanding its origin and cause, as well as learning from these experiences, the occurrence of incidents and accidents can be reduced, and the effects minimised.

Keywords: *aviation, human error, mistake, violation*

1. Introduction

Human performance is a complex process, where humans act in synergy with many other factors, including environment, technology, various cultural aspects and other participants in it (Strauch, 2002). A mismatch in interaction of humans and other components in this process leads to error which is an integral part of human performance, resulting from physiological and psychological limitations inherent in humans (Amalberti, 2001). Error has been a contributing factor to the majority of incidents and accidents in any field of human activity. Approximately 80% of aviation events are caused by a decrease in human performance, and therefore it must be scrutinised in all facets of the aviation system (Naranji et al., 2015). As aviation safety depends on minimising error in all constituents of this compound system, it is primarily important to define and classify errors, in order to better understand their nature and causes, and investigate them (ICAO, 1993). Human error can be commonly defined as 'the failure of planned actions to achieve their desired goal' (Reason, 2005:57). There are basically two ways in which this failure can occur:

- the plan is adequate but the associated actions do not go as intended;
- the actions may go entirely as planned but the plan is inadequate to achieve its intended outcome.

Strauch (2002:21) defines error as 'an action or decision that results in one or more unintended negative outcomes'. Hansen (2006:74) defines error as 'a voluntary and deliberate action by a human interacting with another system that exceeds established tolerances defined by that system'. The ability of humans to decide which of the numerous inputs received are significant in choosing the correct action is important in understanding why we have human error.

2. Error Classification

There are a number of error taxonomies, but in many domains of application two kinds of categorisation are used together: a classification by consequences, where the focus is on inadequate performance of an action, and a classification by psychological origins, with a focus on mental antecedents of the error (Reason, 2005). Human errors can be basically split into *errors of omission* when crew members fail to perform a required task, and *errors of commission* when crew members carry out a task incorrectly or do something that is not required. Uncontrolled movements, such as reflexes, are not considered errors (Kern, 1998).

Reason (1990) identifies four types of error: slips, lapses, mistakes and violations. *Slips* are observable actions related to attentional failures. When an action is carried out incorrectly, this error is classified as a slip. Norman (1981) makes a difference between verbal and action slips. An example of a verbal slip is pronouncing a wrong call sign, while pressing a wrong button is an action slip. *Lapses* are internal events related to memory failures. When an action is simply omitted or not carried out, the error is termed a lapse. An example of a lapse is omitting items in a checklist or forgetting a step in a process. Slips and lapses occur during the performance of routine tasks, usually in familiar surroundings, and are provoked by distraction from the environment, preoccupation, a change in the plan or the environment itself. They are also termed failures of execution.

Mistakes are planning failures or failures of intention, where the plan is inadequate to achieve the objectives. They are likely to be more complex and more dangerous than slips, and also more difficult to detect, as there is no departure of action from intention. An example of a mistake is issuing a wrong instruction. Rasmussen (2004) classifies mistakes as rule-based mistakes that occur in familiar or training situations and knowledge-based mistakes that are related to new situations.

Violations are deliberate or erroneous actions deviating from safe operating practices, standards or rules, for example exceeding the speed limits. However, individuals may intentionally deviate from norms, in order to complete an action without creating any harm. Violations of this nature are errors in judgement and may not automatically result in disciplinary measures. They can be categorized as:

- situational violations – committed in response to factors in a specific context, such as time pressure or high workload;
- routine violations – committed in response to situations in which compliance with established procedures makes task completion difficult, and causes applying workaround procedures, which eventually become routine. If well grounded, some routine violations may be incorporated as an accepted procedure after safety assessment;
- organisationally induced violations – may be considered as an extension of routine violations, and tend to occur when an organisation attempts to meet increased output demands by ignoring or stretching its safety defences (ICAO, 2012).

Reason (2016) differentiates between *active failures* or unsafe acts (both errors and violations), committed by those at the so-called sharp end of the system, whose actions can have immediate adverse consequences, and *latent failures* resulting from decisions taken at the higher organisational levels, regarding inappropriate design of equipment, training, supervision or poor communications and delegation of roles and responsibilities. Their damaging consequences may lie dormant for a long time, and become evident when combined with active failures and local triggering factors to breach the system's many defences. This is known as the *Swiss cheese model of accident causation* or the Reason model, and it proposes that all accidents include a combination of both active and latent conditions.

Latent failures are important for accident prevention for two reasons: if not resolved, the probability of accident recurrence remains high, regardless of what other action is taken; if removed, they can be an efficient route to accident prevention.

3. Causes of error

Humans commit errors for a number of reasons. They primarily err because of three fallible mental functions - perception, attention, and memory, that limit the ability to processing information (Hansen, 2006:66). They also commit errors because of influences such as stress, distraction, illness, visual illusions, spatial disorientation, old age, immaturity, cultural beliefs or inadequate training. They also err because a task or an action is beyond their normal capabilities (Adams, 2006).

Errors are not the cause, but rather the result of many interacting factors: personal, task-related, situational and systemic, and the consequence of different preconditions for their occurrence (Reason and Maddox, 2005). These preconditions, also termed precursors or antecedents, are causes of error, and can range from fatigue, workload, poor communication, information processing to decision making (Strauch, 2002).

International Civil Aviation Organisation (ICAO) lists over 300 human error precursors. However, since 1993 all areas of the aviation industry have found the concept of *Dirty Dozen* a useful introduction to understanding human error in their businesses, organisations and workplaces. This concept refers to twelve most common error preconditions to incidents or accidents.

Image 1. The Dirty Dozen (created by the author)

4. Understanding Human Error in Aviation

Most aircraft incidents and accidents are the result of errors made by the people responsible for operating the aviation system. These people could be pilots, air traffic controllers, maintenance staff or executive managers of various aviation organisations. The consequences of human error in this field can range from no injury or loss of life, but with danger to safe operations, which is termed *incident*, to casualties and major damage to aircraft, which is termed *accident* (ICAO, 1993).

While errors resulting in incidents, accidents and loss of life are mostly made by pilots or air traffic controllers and draw more public attention, those made by maintenance staff also need to be taken seriously, since they can result in fatalities and damage to aircraft as well, and entail significant consequences to air traffic (Latorella and Prabhu, 2000:133). Some of the errors committed by these people are the result of deliberate violations of rules and procedures. However, even the majority of errors resulting from violations do not come from any intent to harm anyone or commit a crime (Adams, 2006).

It has generally been assumed that errors and violations are limited to incidents and accidents. Recent data from flight operations monitoring programs indicate that errors and violations are quite common.

According to one University of Texas LOSA database, in approximately 60% of the studied flights at least one error or violation was observed, the average being *1.5 errors per flight.* A quarter of the errors and violations were mismanaged or had consequences (an undesired aircraft state or an additional error). The study also indicated that a third of the errors were detected and corrected by the flight crew, 4% were detected but made worse, and more than 60% of errors remained undetected. These data underline the fact that errors are part of normal flight operations and, as such, usually are not immediately dangerous (OGFA Briefing Note).

The SHELL Model

A basic aid to understanding human error is the SHELL model, a conceptual tool used to analyse the interaction of multiple system components. It comprises five building blocks, with the name derived from the initial letters of its components:

a) Software (S) – standard rules, operating procedures or documents,
b) Hardware (H) – functional systems and equipment,
c) Environment (E) – the working environment in which the rest of the L-H-S system must function, social and economic climate, and the natural environment,
d) Liveware (L) – humans in the workplace (flight crews, air traffic controllers, maintenance personnel, management and administration).

The model places emphasis on the human being (liveware) and its interfaces with other components of the system. An incongruity between the liveware and other components contributes to human error. Thus, these interactions must be assessed and considered in all sectors of the aviation system (ICAO, 2012:19). Each of the interfaces can be a source of error (Dumitru and Boşcoianu, 2015:4):

- L-H – errors due to improper placement of displays and control devices,
- L-S – delays and confusion due to inadequate maps and documents,
- L-E – errors caused by environmental factors (noise, temperature, vibration etc.),
- L-L – the interaction between people, which directly affects crew performance.

The TEM Model

The Threat and Error Management (TEM) framework is a conceptual model aimed at understanding the inter-relationship between safety and human performance in the operational context. Originally developed for flight deck operations, TEM can nonetheless be used at different levels and sectors within an organisation, and across different organisations within the aviation industry. One of its objectives is to understand error detection and response, rather than focusing solely on error causality (Maurino, 2005).

The model comprises threats, errors and undesired states. Threats are events that occur beyond the influence of pilots or controllers. Errors are actions or inactions that lead to deviations from organisational or individual intentions or expectations. Undesired states are defined as operational conditions where an unintended traffic situation results in a reduction of safety. TEM classifies errors based upon the primary interaction of the pilot or flight crew at the moment the error is committed. It proposes that threats and errors are part of everyday aviation operations, and must be managed by both pilots and air traffic controllers, as they carry the potential to generate undesired states. Undesired state management largely represents the last opportunity to avoid an unsafe outcome (ICAO, 2005).

PEAR

Similar to SHELL, this model explains human performance in aviation maintenance, with its name derived from initial letters of factors: people who do the job (P), the environment in which they work (E), the actions they perform (A), and the resources necessary to complete the job. It provides methods for identifying and controlling many of the potential hazards within a maintenance organisation and should be an integral part of its safety management system – SMS (Johnson and Maddox, 2007).

4.1 Pilot Error

Investigators avoid the term pilot error, as accidents typically result from a combination of causal factors and must overcome several lines of defence. ICAO therefore adopted Reason's model of accident causation in 1993 aiming to better understand the role of human factors in aviation incidents and accidents (Strauch, 2002). The study and analysis of various reports and databases shows that approximately 80 percent of all aviation accidents are related to human (primarily pilot) errors, with the majority of them occurring during landing (24.1 %) and take-off – 23.4 % (Naranji et al., 2015:72).

Pilot error was reported a probable cause in 38% of the major airline crashes, 74% of the commuter/air taxi crashes, and 85% of the general aviation crashes (Li et. al., 2001:52). During the flight, pilots are exposed to various threats that occur beyond their influence. Among them, terrain accounts for 58%, adverse weather 28%, aircraft malfunctions 15%, unusual traffic commands 11%, external errors (air traffic control, maintenance, cabin, dispatch and ground crew) 8%, and operational pressures for 8% of threats to flights. The results of the line operations safety audit confirm that threat and error are ubiquitous in the aviation environment, with an average of *two threats and two errors observed per flight* (Helmreich, 2000:782-3).

Incorrect or incomplete pilot-controller communication is also a causal or circumstantial factor in many incidents or accidents. An error committed by a pilot is a threat to air traffic control (ATC), and vice versa, since their communication is performed in a continuous loop. It may be compromised by various language issues, ranging from strong accent, inadequate language proficiency, to the use of non-standard phraseology or two languages on the same frequency, or two or more ATC units sharing the same frequency; they are also considered threats under this category (ICAO, 2005). Examples of pilot error include:

- slips: wrong entry in the flight management computer (incorrect altitude, speed, heading);
- lapses: missing or wrong information exchange, misinterpretation of instructions, incorrect readback;
- mistakes: unnecessary navigation through adverse weather, missed taxiway/runway, performing a checklist from memory;
- violations: ignoring the clearance issued by ATC, pushing duty time limits (Helmreich, 2000).

The TEM model assists in educating flight crews that, when the aircraft is in an undesired state, their basic task is to manage such state rather than the error committed. As part of the normal discharge of their operational duties, pilots must employ countermeasures to keep threats, errors and undesired aircraft states from reducing margins of safety in flight operations.

Empirical observations during training and checking suggest that as much as 70% of flight crew activities may be countermeasure-related. Examples of countermeasures would include: checklists, briefings, standard operating procedures (SOPs), personal strategies and tactics, professional training, as well as system-based countermeasures, such as Airborne Collision Avoidance System (ACAS), Traffic Collision Avoidance System (TCAS) and Ground Proximity Warning System - GPWS (ICAO, 2005).

4.2 Air Traffic Control Error

During typical operations, air traffic controllers also have to take various complexities into account, including adverse meteorological conditions, airports surrounded by high mountains, congested airspace, aircraft malfunctions, and/or errors committed by other people outside of the ATC room (i.e. flight crews, ground staff or maintenance workers). The TEM framework considers these complexities as threats because they all have the potential to negatively affect ATC operations by reducing margins of safety (Maurino, 2005).

Communication between controllers and pilots is a vital part of ATC operations, and communication breakdown has been a causal factor in a number of serious aviation accidents. Three out of seven contributors to safety occurrences recorded within the EVAIR (Eurocontrol Voluntary Air Traffic Management (ATM) Incident Reporting) database showed an increase in the number of reports during the summer season 2016 regarding: air-ground communication, mistakes and lapses (Eurocontrol, 2017). In comparison with other contributors, air-ground communication has the highest percentage (34%), and is the most common contributor to errors such as runway and taxiway incursions, level busts, call sign confusion and go-around movements of aircraft.

Slips and lapses account for 6.1% of errors. They include: wrong call sign, inappropriate language and accent, non-standard phraseology, misunderstanding/misinterpretation (slips), forgetting information, loss of awareness, omission of hear-backs, situation not conveyed by pilots, lack of monitoring, perception or receipt of information, timing, etc. (lapses). Mistakes account for 28.4% of safety occurrences and refer notably to failures in judgement, planning, decision-making and monitoring. The remaining contributors to safety occurrences are errors made in the following areas:

- traffic information – incorrect, late or no information provided (13.5%);
- ATC clearance/instructions – wrong runway, turn direction, assigned speed, track/heading, climb/descent or approach clearance (6%);
- coordination problems between positions within the ATC suite and with sectors in the same unit (3.8%);
- traffic and airspace problems related to weather or traffic complexity (8.6%).

The TEM framework again proposes that threats and errors are part of everyday aviation operations that must be managed by ATC. Regardless of the type of error, its effect on safety depends on whether the ATC detects and responds to the error before it leads to an undesired state or, if unaddressed, to an unsafe outcome. From the safety perspective, operational errors that are timely detected and promptly countered or managed, and errors not leading to undesired states or not compromising safety in ATC operations become operationally inconsequential (ICAO, 2005).

Similar to pilots, examples of ATC countermeasures would include: checklists, briefings, SOPs, personal strategies and tactics, professional training and system-based countermeasures, such as Minimum Sector Altitude Warning (MSAW) and Short-Term Conflict Alert (STCA) systems. Another solution is Controller-Pilot Data Link Communication (CPDLC), a two-way data-link system by which controllers can transmit non-urgent strategic messages to an aircraft as an alternative to voice communications, with messages displayed on a flight deck display (Maurino, 2005).

4.3 Maintenance Error

Aviation maintenance and inspection tasks are part of a complex organisation, where individuals perform various tasks in an environment with time pressures, sparse feedback and sometimes difficult ambient conditions. Their work is influenced by a number of contributing factors known as the previously mentioned Dirty Dozen. It has been estimated that 80 – 90% of them are under management control, while the remaining 10 – 20% are under the control of a maintenance technician or inspector. Therefore, management can make changes to reduce or eliminate most contributing factors to errors and violations and thereby reduce the probability of future, similar events (Boeing, 2016:1-2). Maintenance and inspection errors have been the primary cause of 6% of aircraft accidents and have contributed to an additional 9% of the accidents from 1982 through 1993. For example, failure to replace horizontal stabilizer screws on a Continental Express aircraft resulted in in-flight leading-edge separation and 14 fatalities (Rankin, 2000:795). A major airline shows the distribution of 122 maintenance errors over a period of three years to be: omissions (56%), incorrect installations (30%), wrong parts (8%), other errors – 6% (Latorella and Prabhu, 2000:141). Based on Reason's classification, the following errors are specified in the Maintenance Error Decision Aid (MEDA) system:

- part not installed correctly (error of commission or a slip),
- part not installed at all (error of omission or a lapse),
- part installed in the wrong location (slip),
- not enough oil added during servicing (lapse),
- inspector did not see the fault (lapse),
- tool left in the engine cowling (lapse).

Violations include an intentional deviation from regulations, a company policy, process or procedure. They are further classified as:

- routine – a maintainer engages in practices, condoned by management, that bend the rules,
- situational – a maintainer strays from accepted procedures to save time, bending a rule,
- exceptional – a maintainer wilfully breaks standing rules disregarding the consequences.

Based on the SHELL and PEAR models, aviation maintenance system includes four components (operators, equipment, documentation and task) and suggests that they interact over time, as well as within physical, social or organisational environments (Latorella and Drury, 1992). In addition to incidents and accidents, maintenance errors entail other consequences – air turn-backs, delays in aircraft availability, gate returns, inflight shutdowns, diversions to alternate airports, maintenance rework, damage to maintenance equipment, and injury to maintenance personnel, with 50% of all engine-related flight delays and cancellations due to improper maintenance, and 33% of all military aviation equipment malfunctions resulting from poor maintenance or improperly applied maintenance procedures. These consequences ultimately affect customer satisfaction, airline company productivity and profit (Latorella and Prabhu (2000).

5. Error Investigation

Methods of investigating human error range from studying different sources, such as cockpit voice recorders, air traffic control tapes, flight data recorders, event databases, self-reports, accident reports, simulator studies, case studies, and using different conceptual models. All accident investigation techniques are *post hoc* methods, as errors are identified after the events, and tend to be invisible until they cause an aircraft to miss its ramp time or cause property damage and injuries (Reason and Maddox, 1995:29).

HFACS

The Human Factors Analysis and Classification System (HFACS), based upon Reason's model, provides a tool to assist in the investigation process, target training and prevention efforts. Investigators are able to systematically identify active and latent failures within an organisation that culminated in an accident. The goal of HFACS is not to attribute blame; it is to understand the underlying causal factors that lead to an accident. It describes human error at each of four levels of failure: unsafe acts of operators (e.g. aircrew), preconditions for unsafe acts, unsafe supervision, and organisational influences. Causes of active and latent failures are identified within each of the levels. In theory, at least one failure will occur at each level leading to an adverse event. If at any time leading up to the adverse event one of the failures is corrected, the adverse event will be prevented. By using HFACS organisations are able to identify the breakdowns within the system that allowed an accident to occur. It can also be used proactively by analysing previous events to identify recurring trends and weaknesses in human performance and system deficiencies, and to implement targeted, data-driven interventions aimed at reducing accident and injury rates.

SHELL

The SHELL model helps optimise the relationship between people and their activities within the aviation system. Investigators can use this model to collect data on human performance and component mismatches during event analysis, or to understand the relationships between systemic human factors during operational audits, which can help reduce errors, enhance safety, and improve processes (ICAO, 2012).

EVAIR

The Eurocontrol Voluntary AIR Traffic Management (ATM) Incident Reporting exchange platform (EVAIR) gathers information on operational safety concerns in the areas of ATM and air navigation services (ANS). The data is analysed in order to draw lessons learned, and reports promulgated to the stakeholders, aiming to manage and reduce errors that occur during operations. It is based on a collaboration among aircraft operators, airline associations, air navigation service providers (ANSPs) and airports.

TOKAI

The Toolkit for ATM Occurrence Investigation (TOKAI) is a web-based application that enables users to report, investigate and take corrective actions following incidents and accidents, known as occurrences. The entire process includes: notification of an event, data gathering, investigation, risk assessment (through the risk analysis tool), conclusions, safety recommendations and statistics.

MEDA

The Maintenance Error Decision Aid (MEDA) is a structured process used to investigate events caused by maintenance staff and/or inspector performance. The fundamental philosophy behind MEDA is:

- maintenance-related event can be caused by an error, violation or their combination,
- maintenance errors are not made on purpose, and are caused by a series of contributing factors,
- violations, although intentional, are also caused by contributing factors,
- most of these factors are under the control of management, and can be improved in order to prevent future, similar events.

MEDA has five categories for reporting an error occurrence: general and operational event data, error classification, contributing factors and corrective actions (Rankin, 2000).

6. Error Management

Managing human error includes the following strategies:

- error prevention – avoiding the error completely, which is possible only in some specific cases and requires design-based solutions,
- error reduction – minimising both the likelihood and magnitude of the error,
- error detection – making errors apparent as fast as possible, thereby enabling recovery,
- error recovery – rapid regaining of the system's safe state after an error has been committed;

- error tolerance – making the system sustainable despite errors, i.e. minimizing their consequences (ICAO, 2005).

6.1 Error Detection

The most obvious response to errors is to identify the causal mechanisms and alter the system in a way that it prevents their recurrence. This requires a sophisticated error detection system, capable of identifying complex interactions, and the impractical assumption that human variability is minimal (Latorella and Prabhu, 2000:137). Errors can be detected:

- by the person that committed the error (self-monitoring),
- by another person (fellow worker, management, inspector or investigator),
- by the system hardware and software.

Slips are usually easy to detect quickly and do not have immediate serious consequences due to built-in system protections. Lapses are more difficult to detect and therefore may also be more likely to have consequences. Mistakes are even more dangerous, because the person committing them believes that he or she is doing the correct thing and thus carries on with the action despite a growing number of warning signs that things are not going right. Violations are similar to mistakes but with an increased potential to deviate to an abnormal operation and associated increase in risk. Many violations are tempting because they often bring benefits without any apparent drawbacks (Helmreich, 2000).

6.2 Managing Errors

Errors can be primarily managed by creating an error-tolerant environment and using a number of technological solutions, models and methods. One of the potential engineering solutions is that of automation. However, automation can often increase the impact of human error, and shift its location from the operator to the designer, the maintenance personnel, and the supervisor who must deal with automation problems and failures. In air traffic management (ATM), full automation is not considered feasible in the near future because human traits such as flexibility and adaptability, problem-solving and decision-making capabilities are needed to optimise dynamic ATM situations. Therefore, automation, or rather computerised support, could help ATM just cope with human error, but not prevent it (Eurocontrol, 2002).

Numerous studies have showed that cockpit automation systems also pose a danger of disengaging the pilot from the operations. One of the solutions is using an augmented cognition system (ACS) with other systems. The integration of ACS into the flight management system (FMS) allows the pilot to precisely assess the aircraft's state at each segment of the flight. Its decision making and risk-assessment algorithm enables the prioritisation of pilot tasks and provides instruction via voice and display (Latorella and Prabhu, 2000).

The mechanisms causing slips and lapses function at an unconscious level. Therefore, even if slips and lapses can be reduced through good design of the interfaces, i.e. error-tolerant interfaces, procedures and environments, it is impossible to prevent all of them. Reason (1990) suggests that systems could be designed to minimise violations by changing the organisational culture and social norms, and individual beliefs and values. Proficiency errors suggest the need for language or technical training, whereas communication and decision-making errors call for team training. Procedural errors may result from human limitations or from inadequate procedures that need to be changed. Violations can stem from a culture of non-compliance, perceptions of invulnerability, or poor procedures (Helmreich, 2000).

In addition to the TEM and MEDA models, there are other models and methods available for managing human error and performance in aviation, including:

- Crew Resource Management (CRM) – focuses on interpersonal communication, leadership, and decision making in the cockpit;

- Single Pilot Resource Management (SPRM) – similar to CRM but focuses more on situational awareness, time, workload, decision making and automation management;
- Line Operations Safety Audits (LOSA) – designed to collect data on crew performance, and then analyse and understand the organisational factors behind any errors;
- Safety Management System (SMS) – a management process aimed at reducing human error by identifying and managing risk in the workplace;
- Safety Cultures – the attitudes, beliefs, perceptions and values that employees share with regard to workplace safety.

7. Conclusion

Human performance is a complex process, where humans act in synergy with many other factors, including environment, technology, various cultural aspects and other participants in it. A mismatch in interaction of humans and other components in this process leads to error which is an integral part of human performance, resulting from physiological and psychological limitations inherent in humans. Error has been a contributing factor to the majority of incidents and accidents in any field of human activity.

Approximately 80% of aviation events are caused by a decrease in human performance. As aviation safety depends on minimising error in all constituents of this compound system, it is primarily import to understand their nature and causes. A holistic approach to error also needs to be taken for its investigation and analysis, since they are the product of many interacting factors: personal, task-related, situational and systemic. The aim of comprehending why people make errors is to elaborate safety recommendations and technological solutions that will decrease the likelihood of aviation events, and mitigate the consequences. A prerequisite of effective error management is to break free of the blame cycle, and to recognise that human actions are invariably constrained by factors beyond an individual's immediate control.

Errors can be managed and reduced primarily by creating an error-tolerant environment rather than punitive environment, improving error training, and using a number of technological models, aids and methods. Human error cannot be eliminated, but by understanding its origin and cause, as well as learning from these experiences, the occurrence of incidents and accidents can be reduced, and the effects minimised.

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