Human Force Efficiency: A Quantitative Study of Workforce Management in Aviation Industry

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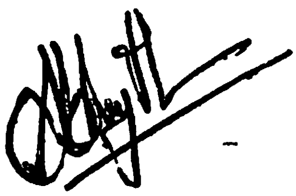

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Yours Sincerely

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Abstract

The world's first scheduled passenger airline service took off on 1Jan1914, operating between St. Petersburg and Tampa, Fla. It marked the beginning of commercial aviation and we have witnessed exponential growth in the sector. The commercial airline is an extremely competitive, safety-sensitive, high technology service industry. The term "human factors" has grown increasingly popular as the commercial aviation industry has realised that human error, rather than mechanical failure, underlies most aviation accidents and incidents. Human error has been documented as a primary contributor to more than 70 percent of commercial airplane hull-loss accidents. Current human factor management programs have not succeeded to the degree desired. Many industries today use performance excellence frameworks such as the Baldrige National Quality Award framework to improve over-all organisational effectiveness, organisational culture and personal learning and growth. Survey and research conducted by various institutions have revealed that a consistent problem with aviation human factors and the need for a more integrated framework to manage human factor problems in aviation industry.

The object of this study is to understand the importance of human factors in the aviation industry. This study will also help to understand how human performance is improvised by considering the technology, design, training, policies, or procedures to help humans perform better.

Chapter 1: Introduction

1.1 Overview

Humans have dreamed of flying and have attempted to achieved from the earliest days. Examples of Gods who were gifted with flight were mentioned in Greek and Roman mythology. 1900-1914 is known as the Pioneer Era in history of aviation as it marked remarkable inventions and flights from Wright Brothers. That showed the beginning of an industry which expanded all over the world. Aviation provides the only rapid worldwide transportation network, which makes it essential for global business. It generates economic growth, creates jobs, and facilitates international trade and tourism. According to recent estimates by the cross-industry Air Transport Action Group (ATAG), the total economic impact (direct, indirect, induced and tourism-connected) of the global aviation industry reached USD2.7 trillion, some 3.5 percent of world's gross domestic product (GDP) in 2014.

The air transport industry also supported a total of 62.7 million jobs globally. It provided 9.9 million direct jobs. Airlines, air navigation service providers and airports directly employed over three million people. The civil aerospace sector (the manufacture of aircraft, systems and engines) employed 1.1 million people. A further 5.5 million worked in other on-airport positions. 52.8 million indirect, induced and tourism-related jobs were supported by aviation.

These estimates do not include other economic benefits of aviation, such as the jobs or economic activity that occur when companies or industries exist because air travel makes them possible, the intrinsic value that the speed and connectivity of air travel provides, or domestic tourism and trade. Including these would increase the employment and global economic impact numbers several-fold. One of the industries that relies most heavily on aviation is tourism. By facilitating tourism, air transport helps generate economic growth and alleviate poverty. Currently, approximately 1.2 billion tourists are crossing borders every year, over half of whom travelled to their destinations by air. In 2014, aviation supported over 36 million jobs within the tourism sector, contributing roughly USD892 billion a year to global GDP. Source: IATA

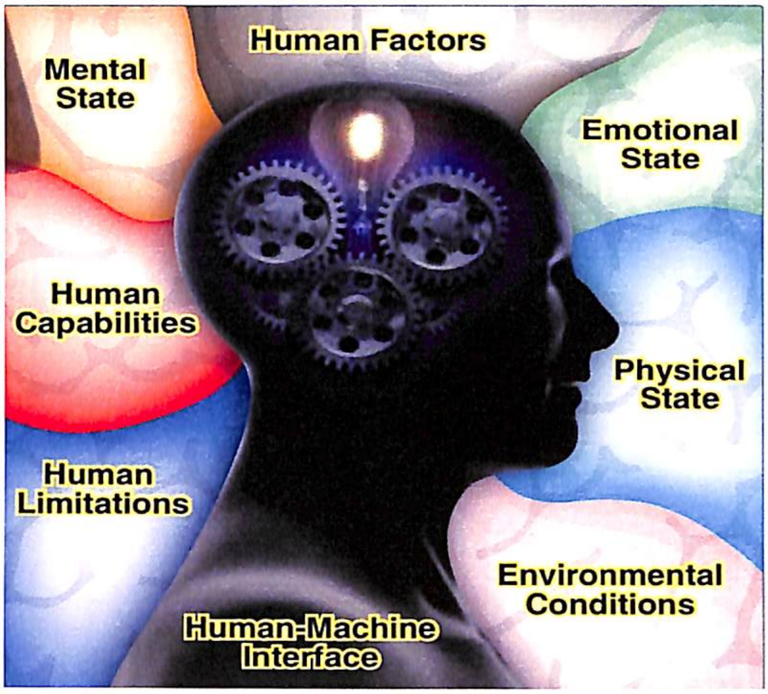

Figure 1: Human factors and how they affect people

1.2 Background

The aviation industry is an extremely competitive, safety-sensitive, high technology service industry. Employees and customers, the people working in every department and machines must be the arena of an organisations core competence. Human factors play a vital role in Aviation Operations. Human errors which contribute to more aircraft incidents and accidents than any other single factor. This include errors by the flight crew, maintenance personnel, air traffic controllers, ground support staff and others who have a direct impact on flight safety. Research has shown that poor quality regarding management, decision making, teamwork, employee motivation or communication can translate into loss of market share, loss of organisation assets, and above all, loss of life. Hence the traditional product centred industrial model of corporate structures and industrial relations inappropriate in a safety sensitive, customer service-centric environment.

Air transport is the safest way to travel. Global safety standards and a harmonised approach formulated cooperatively by governments, regulators, manufacturers, industry associations and operators have been successful in reducing the rate of incidents and accidents. The efforts, however, cannot stop. In a constantly changing world, aviation operations must continue to adapt so that they adequately address emerging issues and apply lessons learned to strengthen the industry's defences against accidents.

Since human error is a major contributor to aviation incidents and accidents, human factors must be an important focus of any aviation safety strategy. Whether for off-line safety analysis or within real-time operations, there is always a need to improve understanding of human performance in an operational context. Human factors provide a universal basis to tie all the ingredients of risk management together into a meaningful whole.

1.3 Purpose of the Project

This dissertation explains the strategic importance of including human factors in aviation sector. It covers the concept of resilience to errors and the need to maintain a current view of safety by challenging both operational assumptions and legacy safety principles. Reducing human performance variability by standardising behaviours and thereby increasing overall system predictability is the main goal of aviation human factors strategies.

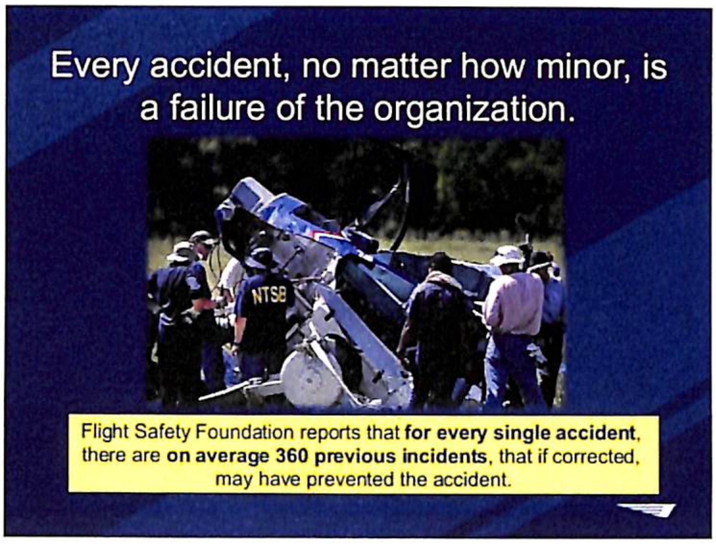

Figure 2: Flight Safety Foundation

Chapter 2: Literature Review

The basic field of human factors has matured over time, and the human factors focus on aviation has compiled a long list of achievements. The cumulative effect of the application of these human factors successes to aviation has been well-documented. There is also a continuing human factors research effort that has created a strong inventory of new potential countermeasures. Aviation human factors has advanced through the following phases:

- Beginning in the 1920s and continuing to the present in modified form, human factors has focused on pilot selection to control variability and increase safety.
- The advent of World War II added a basic ergonomics focus on the design of the human interface with equipment that continues to this day.
- The introduction of the first big jets in the early 1960s was accompanied by the emergence of high-fidelity, motion-based simulator training that supported practice and proficiency on
- manoeuvres and recovery procedures that are too dangerous to train in aircraft during flight.
- A focus on non-technical skills and crew resource management (CRM) training emerged in the early 1980s.
- Highly automated flight decks and flight envelope protection also were introduced in the late 1980s.
- Human factors regulations (e.g., flight crew licensing, operations, maintenance, design) received added impetus in the early 1990s.
- Beginning in the mid-1990s, enforced supervision, flight data recorder analysis, line-oriented safety audits (LOSA) and similar programs became commonplace.

2.1 Human Factors & Accidents

The term "human factors" is used in many ways in the aviation industry. The term is, perhaps, best known in the context of aircraft cockpit design and Crew Resource Management (CRM). However, those activities constitute only a small percentage of aviation-related human factors, as broadly speaking it concerns any consideration of human involvement in aviation. The 2003 International Air Transport Association (IATA) Safety Report found that in 24 of 93 accidents, a maintenance-caused event started the accident chain. Overall, humans are the largest cause of all airplane accidents (see fig.2). Maintenance errors can also have a significant effect on airline operating costs. It is estimated that maintenance errors cause

- 20 to 30 % of engine in-flight shutdowns at a cost of US$500,000 per shutdown.
- 50 % of flight delays due to engine problems at a cost of US$9,000 per hour.
- 50 %of flight cancellations due to engine problems at a cost of US$66,000 per cancellation.

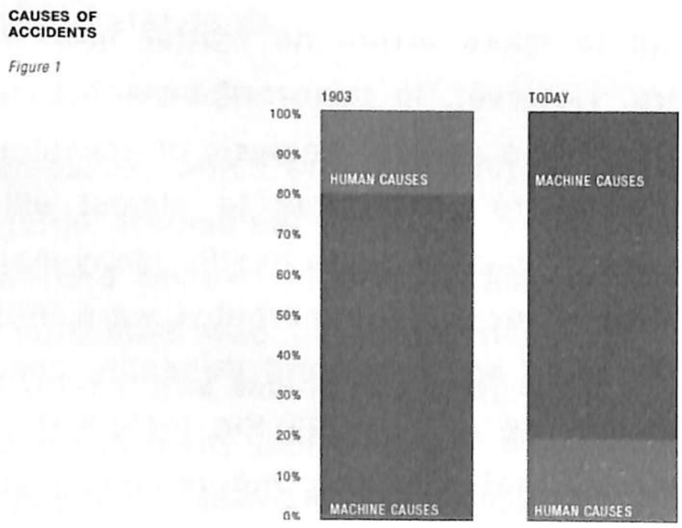

Figure 3: Causes of Accidents

Office ergonomics concerns all the factors that impact on the health, wellbeing and productivity of people who work in an office environment, from chairs, desks and computers to shift patterns, work practices and stress management. Work equipment can have a considerable impact on user comfort, health, wellbeing and performance. Poorly designed office equipment can influence headaches, job-related stress, and musculoskeletal problems primarily affecting the lower back, neck/shoulders and upper limbs. Research has shown that effective office ergonomics interventions on average reduce the number of musculoskeletal problems by 61%, reduce lost workdays by 88% and reduce staff turnover by 87%. The cost benefit ratio is on average 1:1.78 with a payback period of 0.4 years. Human Factors studies are often conducted to assess workflow including:

- How specific individuals, teams and work groups collaborate.
- The specific work tasks performed within different job roles to identify the need for task specific workspaces and how they should be designed.
- How information is exchanged and communicated.
- How to ensure that critical knowledge is communicated correctly, completely, clearly and concisely.

Humans tend to make errors no matter how well trained and motivated they are. However, in the workplace, the consequences of such human failure can be severe. Analysis of accidents and incidents shows that human failure contributes to almost all accidents and exposures to substances hazardous to health. Many major accidents for example. Texas City, Piper Alpha, Chernobyl were initiated by human failure. In order to avoid accidents and ill-health, companies need to manage human failure as robustly as the technical and engineering measures they use for that purpose. Understanding different types of human failure can help identify control measures but you need to be careful you do not oversimplify the situation. The likelihood of these human failures is determined by the condition of a finite number of performance influencing factors, such as design of interfaces, distraction, time pressure, workload, competence, morale, noise levels and communication systems. Many aspects of human factors are associated with the operational safety of commercial airplanes, including the following:

- Design factors associated with aircraft controls, aircraft system controls, warning systems, air traffic control systems, flight deck, passenger seating and egress, etc.
- Operational factors associated with the selection and training of flight crews, crew assignment policies related to the distribution of experienced personnel and the minimisation of flight crew fatigue, checks on crew members' health, and policies on prefight information.
- Maintenance factors related to training maintenance workers; the clarity of maintenance procedures; and designing aircraft equipment and maintenance tools to make it easier for workers to perform maintenance, avoid errors, and detect abnormal conditions.
- National and international regulatory factors associated with airworthiness standards, separation standards, and communications standards.

2.2 Complexity of Human Factors

Current processes, which are both thorough and complex, have resulted from a large accumulation of flight experience, analytical and computer studies, and reviews of human factors. All this information represents a complicated web of interrelated factors that makes it difficult to define a clear and simple road map for progress. Complexity, however, is inherent in many human factor issues. Additional work in fields such as cognitive science and fundamental neuroscience is progressing rapidly and is likely to offer valuable insights soon. First, it should encourage the development of processes and systems that would improve the selection and presentation of necessary information, assigning to automated systems the tasks that systems do best and allowing people to continue doing the tasks that people do best. Second, it should help define the type of automation that can reduce the workload of flight crews and air traffic controllers in the crucial moments when a situation must be assessed quickly and accurately.

Around 1487, Leonardo Da Vinci began research in the area of anthropometrics. The Vitruvian Man, one of his most famous drawings, can be described as one of the earliest sources presenting guidelines for anthropometry. Since its inception, the aviation community has been constantly developed through research and development to reduce human factor errors and its operational/organisational impact. Most programs currently implemented are designed to identify the Human Factor errors, educate the personnel on their causal potential, suggest ways to contain and correct the problem and create a Human Factor error-free environment. While many of these programs have truly made the aviation work environment safer, human factor errors continue to persist today. Research is optimized by incorporating the many disciplines that affect human factors and help to understand how people can work more efficiently and maintain work performance. There is a need for a more integrated and holistic approach to human factor management.

2.3 Human Factor Management

Human factors are issues that affect how people do their jobs. They are the social and personal skills, such as communication and decision making which complement our skills. These are important for safe and efficient aviation operations. The objective of the research is to provide an overall system that reduce the potential for human error, increase system availability, lower lifecycle costs, improve safety and enhance overall system performance. The outcome of these functions is two-fold, as follows: To enhance the effectiveness and efficiency with which work and other human activities are carried out; and to maintain or enhance certain desirable human values (e.g., health, safety, satisfaction). The second objective is essentially one of human welfare and well-being. Aviation human factors programs focus on the people who perform the work and address physical, physiological, psychological, and psychosocial factors.

2.4 Reducing Human Errors

Reducing error and influencing behaviour is the key document in understanding human factors. It gives a simple introduction to generic industry guidance on human factors, which it defines as "Human factors refer to environmental, organisational and job factors, and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety" This definition includes three interrelated aspects that must be considered: the job, the individual and the organisation:

- **The job**: including areas such as the nature of the task, workload, the working environment, the design of displays and controls, and the role of procedures. Tasks should be designed in accordance with ergonomic principles to take account of both human limitations and strengths. This includes matching the job to the physical and the mental strengths and limitations of people. Mental aspects would include perceptual, attentional and decision- making requirements.
- **The individual**: including his/her competence, skills, personality, attitude, and risk perception. Individual characteristics influence behaviour in complex ways. Some characteristics such as personality are fixed; others such as skills and attitudes may be changed or enhanced.
- **The organisation**: including work patterns, the culture of the workplace, resources, communications, leadership and so on. Such factors are often overlooked during the design of jobs but have a significant influence on individual and group behaviour.

2.5 Human Factors in Safety Management System

In other words, human factors is concerned with what people are being asked to do (the task and its characteristics), who is doing it (the individual and their competence) and where they are working (the organisation and its attributes), all of which are influenced by the wider societal concern, both local and national. Human factors interventions will not be effective if they consider these aspects in isolation. The scope of what we mean by human factors includes organisational systems and is considerably broader than traditional views of human factors/ergonomics. Human factors can, and should, be included within a good safety management system and so can be examined in a similar way to any other risk control system.

Table 1: Primary causes of aircraft accidents

Percentage of total accidents with known cases	
Primary Factor	**Percentage %**
Flight Crew	72
Airplane	09
Maintenance	05
Weather	04
Airport/ATC	03
Other	05

Chapter 3: Research Methodology

3.1 Quantitative Descriptive Approach

The research design used for this study is the self-report descriptive research method. A quantitative descriptive approach is used to collect and assess the data. The purpose of the review of the literature is to find the human force efficacy in the aviation industry. After going through various literature reviews on international aviation, researchers tend to analyse the industry at a macro-level. Survey results are the sole source of data collection for this study. The research strategy is database driven drawing upon the business, management, journalistic, academic, and technological databases. A broad range of sources were consulted with a view to construct a snapshot image of key human factor themes found in the commercial airline industry.

3.2 Sources of the Research Method

Sources for this research are based on Secondary Data collection method. There are no targeted rules to decide which methods are the most appropriate for identifying specific research needs. Each method has its strengths and weaknesses, and each is useful if applied appropriate. The sources of the secondary data collected was a combination of completed research from organisations such as NTSB, FAA, Boeing and Airbus as well as a data collection device in the form of industry survey, published printed sources, books and websites etc. Procedures and rules are often written down in manuals and these are a good source of data.

Many sources of information have been used in the course of preparing this document, including text books on human factors, ergonomics, occupational psychology and the like accident and investigation data, such as reports produced by the Air Accidents Investigation Branch (AAIB) and information from the CAA's Mandatory Occurrence Reporting Scheme (MORS) (see) and the ICAO Human

Factors Digests. This document has also drawn on the FAA Human Factors Guide for Aviation Maintenance and various other material from the large body of FAA funded research into human factors and

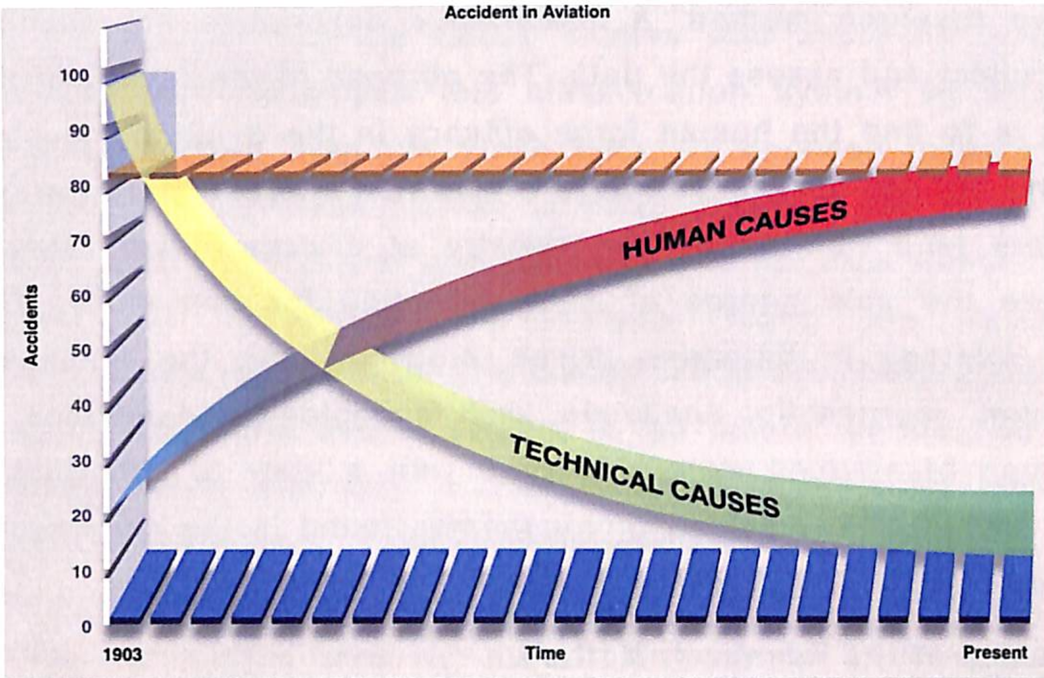

Figure 4: Accidents in Aviation

maintenance engineering. These sources can be accessed via the Internet on http://hfskyway.faa.gov

3.3 Case Studies

The Aviation Herald was used to extract case-study data. The case studies were selected based on outcome severity, so that only crashes (accidents with the potential to cause fatalities of all on board) were analysed. The case studies used here are listed in **Table 2**.

For each case study processed the reports and categorised the errors according to when in the process they occurred. The classification system is shown in the results below, and includes engineering failures, human-error, and weather conditions. Our interest was primarily in the human error conditions, and thus this section has more detail than the others. A total of fifteen cases were processed in this way. The factors influential to a landing approach were divided into three main classes human factors, technical failures and weather stimulus. A fourth category was used to classify the severity of the crash outcome. The classification system was developed in conjunction with the analysis of the cases studies and improved and refined iteratively. We developed this classification system by subjectively extracting factors from the crash data, as opposed to automatically following the slip/lapse/mistake/violation paradigm, since our priority was to build a model that was coherent with the data rather than with conventional constructs. Nonetheless there are recognisable commonalities that emerge. The classification scheme is based on the explicit behavioural events evident in the failure reports. We take an evidence-based approach and avoid inferring anything that is not present in the reports. Consequently, the classification scheme is more likely to be a fault tree, and other implicit behavioural-shaping factors are not represented here. Nor there is any attempt to interpret the data according to some preferred theory of error causality. This does mean that the scheme only captures the surface actions, as opposed to the reasons beneath those. We are comfortable with this approach because the various protagonists in the flight situation respond to each other's explicit behaviours (including lack thereof), and the tacit behavioural-shaping factors are hidden from each other.

Table 2: List of Accidents

Case Number	Airline	Reference
1	RusAir	Rusair T134 at Petrozavodsk on Jun 20th 2011
2	Henan Airlines	Henan Airlines E190 at Yichun on Aug 24th 2010
3	Georgia Airways	Georgian Airways CRJ1 at Kinshasa on Apr 4th 2011
4	Polish Air Force	Polish Air Force T154 at Smolensk on Apr 10th 2010
5	Hewa Bora	Hewa Bora B721 at Kisangani on Jul 8th 2011
6	Fedex MD11	Fedex MD11 at Tokyo on Mar 23rd 2009
7	Afriqiyah A332	Afriqiyah A332 at Tripoli on May 12th 2010
8	Air India Express	Air India Express B738 at Mangalore on May 22nd 2010
9	Agni Air	Agni D228 at Jomsom on May 14th 2012
10	Merapati MA60	Merpati MA60 at Kaimana on May 7th 2011
11	AirBlue	AirBlue A321 near Islamabad on Jul 28th 2010
12	Katekavia	Katekavia AN24 at Igarka on Aug 3rd 2010
13	Conviasa	Conviasa AT42 near Puerto Ordaz on Sep 13th 2010
14	Colgan DH8D	Colgan DH8D at Buffalo on Feb 12th 2009
15	Aviastar Mandiri	Aviastar Mandiri B463 at Wamena on Apr 9th 2009

All human factors are described from the point of view of the person who is pilot-flying, the person of interest in the analysis undertaken. As the human factors were the focus of-this model the human factor category was split into four subcategories: pilot flying actions, procedural failure, decision failure/misjudgement, and team dynamic influences. The first subcategory, pilot flying inability, describes influences which are inherent in the pilot's ability to fly at the time of the accident and can most often be considered as the responsibility of the airline who have a duty to ensure its pilots are competent. The second subcategory, procedural failure, is a failure by the pilot to correctly follow a well-defined or semi-automatic process. Subcategory three, decision failure/misjudgement, describes failures of the individual to interpret sometimes ambiguous or conflicting data to provide a necessary response. The final subcategory, team dynamic influence, defines external influences from other team members which add increased complexity to the pilot's tasks.

Table 3: Summary of Causes

H: Human Factors		QTY
H1	**Pilot Flying Inability**	
H1.1	Lethargy	2
H1.2	Inadequate Training	4
H2	**Procedural Failure**	
H2.1	Checkpoint not Acknowledged	2
H2.2	Improper Planning or Preparation	6
H2.3	Incorrect Procedure Employed	5
H2.4	Bad Approach Profile	6
H3	**Decision Failure/Misjudgement/Disregard**	
H3.1	Advice Disregarded	5
H3.2	Warning Signal Disregarded	8
H3.3	Improper Action Taken to Improve Approach Profile	5
H3.4	Decision Delay or Insufficient Action	5
H4	**Team Dynamic Influence**	
H4.1	Bad Team Dynamics or Communication	5
H4.2	False Information or Information Withheld	2
H4.3	Team Disruption or Confusion	3
H4.4	Conflict of Interests	1
H5	**Cognitive effects**	
H5.1	Excessive workload	
H5.2	Incongruence and Conflicting task demands	

T: Technical Failures		
T1	Propulsion Failure	1
T2	Instrument Failure	2
T3	Landing Gear Failure	1
T4	Navigation System Failure	1
T5	Approach Lighting Failure	1
W: Weather Stimulus		
W1	Wind Shear	2
W2	Lightening Strike	0
W3	Fog/Low Visibility	8
W4	High Winds	0
W5	Heavy Rain	2
W6	Icing Conditions	1
X: Outcome Severity		
X1	Minimal Damage to Aircraft	0
X2	Significant Damage to Aircraft	0
X3	Some Fatalities	8
X4	Full Fatalities	7

The above table provides descriptions and codes for the categories and subcategories used for influence classification. Quantities are given in the right-hand column of the table denoting the number of cases out of the fifteen studied in which each influence type was a prevalent factor. Influences of each type, particularly human factors, may have occurred multiple times during a single landing process but for the purpose of this overview they are only counted once per case study. No special claim is made for this classification scheme.

It is simply an evidence-based summary of the agency apparent in the accident reports. A more comprehensive scheme could be developed underpinned by an error theory of choice. However, that is left for future work, since our present purpose is to explore the feasibility of the production perspective, for which his simple scheme is a enough starting point. The present dataset (15 cases) is intended only to validate the methodology and does not have great statistical power. Nonetheless it is possible to extract some observations and insights.

Taking the process perspective is useful as it teases out where the human-error occurs in the process. The results show that landing crashes are primarily associated with poor-visibility WEATHER as the overall situational variable. The failure sequence itself originates primarily, and relatively consistently, in the process of INITIAL LANDING APPROACH (as opposed to later). The main contributors to failure are human error, specifically types H2 procedural failure and H3 decision failure/misjudgement. First, this model shows that the H2 human procedural errors are prevalent throughout the process but are the dominant error-stream at processes 4.1 to 4.4.

In other words, the antecedents for accidents are occurring when pilots are initially engaging with the landing sequence of processes, which is well before the actual landing approach. Thus, at least in these cases, it is the initial decision-making which makes up the dominant type of human error. These pilots are not following established good practices, not initially nor later. Obviously, pilots do not willingly fly to their doom, and are generally well-trained in the procedures. So why are they ignoring the initial landing processes? We cannot answer that from within this study, but we can ask the questions: Are they over-confident and blasé? Or stressed and distracted? Cognitively over-burdened? Inexperienced or Inadequately trained?

Second, the model shows that H3 human decision errors are crowded at the 4.5 process (initial landing approach). (The H2 procedural errors are also continuing at this stage). These H3 errors are of the 'disregard' type. They are disregarding warning information and not deviating from their disastrous course of action. They display a persistence with a poor decision: having made the initial poor decision these pilots pass over subsequent opportunities to change their decision to a better one. For example, they are not using the go-round loop as much as they might, nor diverting to other airports. These pilots are not open to de-biasing themselves. It would appear they are disregarding disconformity information that is not consistent with their mental model and its associated decisions, i.e. a confirmation bias. Is this a problem with a limited mental model of the aircraft-in-the-situation? Are they feeling subconscious pressure to land the aircraft immediately, and if so why? It is also notable that the decisions that lead to accidents are being made under conditions of low visibility (W3 weather condition). This suggests there could be an interaction between decision-making and the external visual field. What is it about low visibility, as opposed to other weather conditions, that uniquely makes pilots take chances, dispense with procedures, and persist with poor decisions? Putting all this together, a tentative overall recommendation emerges that better de-biasing processes may be needed in the cockpit, specifically at or immediately before initial landing approach (4.5), and especially under conditions of low visibility. Pilots need to recognise the process-stages and situations where it is wise to question their own decisions. We therefore suggest it is useful to consider the phasing of human error relative to the process stages. As this model shows, there are different types of errors at different stages. Consequently, the implication is that programmes to reduce error rates would be more effective were they to focus on the errors at stages, rather than simply treat human error as a lumped parameter.

3.4 Conclusion and findings from the case studies

Fundamental to this model is the thinking that human error is something to be expected, and therefore actively de-biased against. Existing approaches to human error tend to give it a pejorative meaning, treating it as an unnatural, bad, or negligent behaviour that must be stamped out. We are not convinced that is the best way treat it. Specifically, we are concerned that framing human error as negligence immediately sets it up in conflict with the conscientiousness and need for achievement motivation that operators (pilots in this case) may naturally bring to their work, and thereby subconsciously invites operators to deny the possible agency of the effect in their own behaviour. We do not dismiss the severity of the consequences of human error in aviation, but we do feel that it is better to bring human error into the open, to mainstream it with the other processes that are happening at the time, and treat as any other production problem. To the way of thinking that we suggest, human error is one of many production factors the variability of which affects the quality of the outcomes. From a production perspective it may not be possible to eliminate these variables, but it should at least be possible to reduce their effect.

Furthermore, the production perspective strongly suggests that the way to improve processes that are out of control is not by simply adding more output control, but rather involves working with the operators to understand where and why the variability occurs, and then find ways to reduce it. The results show, in the specific cases under examination, that the persistence of initial mistakes can occur even in situations where operators are specifically trained, individually and as a group, to be alert to such behaviours. It suggests that training, knowledge, and team cross-checks are in themselves insufficient to break the failure causality in all cases. Many of the cases could have ended better if the protagonists had questioned their own comprehension.

Early in the processes they adopted what were to be unsuitable mental models of how the craft was performing, e.g. how it was physically interacting with the external environment and how its control systems were interfacing to the pilots. It is apparent that complexity and remoteness of the technology contribute to the difficulty of diagnosing malfunction and comprehending the appropriate course of action, even for well-trained flight-crews working constructively. It is not certain that the development of more knowledge, through more training, will help the situation. The issue is cognitive processes, rather than knowledge per se. In all the examples studied here, the flight-crews did not appear to question the sufficiency of their cognitive constructs, and thus were unable to make a transition to a better understanding of how the system was behaving and where their personal agency should be applied. The need is therefore for a deeper mechanism to de-bias the cognition, especially the diagnostic and agency frameworks at the level of individual protagonists. That is not a novel finding as it is consistent with the literature, but it is support for the method.

3.5 Limitations and Opportunities for Further Research

We have already identified the limitation of the classification scheme (its focus on explicit surface behaviours rather than underpinning cognitive factors), and the poor statistical power of the limited case base. There are additional limitations which are briefly identified below. As this method for analysis requires such a deep analysis of each case in order to gain useful information it is therefore limited to cases for which such information is available. In our specific case we only had access to information that is publicly available, and of the many cases reviewed only a relatively small proportion (those shown) had the necessary quality of data for inclusion. Nor were the full flight records and cockpit transcripts available for this analysis, so it was not possible to infer whether there may have been misinterpretation, information overload, workload, or other team behaviours, unless these were included in the accident report. If more data could be gained by applying this analysis tool to further case studies, statistical analysis of the influences and process stages at which they occur could be carried out. By statistically analysing this data, further trends and relationships may be exposed which could in turn highlight areas for improvement within the aviation sector.

Civil aviation agencies have the type of data required for this methodology and could be encouraged to apply the longitudinal type of analysis that the process perspective enables. Also, our work was limited to the landing phase, and even then, to crashes. There are many other situations that could be explored with this methodology, including other phases in the air travel process, and less negative outcomes. Another limitation, this time a deliberate one, is that the study does not attempt to attribute deeper causality to the actions of the protagonists. The reason for avoiding any deeper attribution of causality is that the risk was too high of having the work captured by one or other of the prevailing paradigms of human error, i.e. an attribution bias. Instead we wanted to see whether the production perspective could, starting from a clean slate, have anything meaningful and insightful to say about human error. The results show that this is indeed the case. Nonetheless the development of a deeper theory of human error, complementary to the present more empirical outcome, is desirable as a future endeavour.

Chapter 4: Findings and Analysis

Identifying the potential for human failure in preventing an accident or exposure to substances hazardous to health requires having a thorough understanding of the task the person is carrying out. This document is not an exhaustive list of task analysis techniques (there are many books published on the subject), but to give examples of techniques commonly used for improving health and safety.

- A thorough understanding of the task can contribute to:
- Accurate and workable procedures;
- Assuring the competence of employees;
- Determining appropriate staffing levels;
- Workload analysis;
- Design of workstations, plant and control systems;
- Person specifications for recruitment;
- Human error analyses as part of risk assessment; and
- Allocation of function i.e. identifying whether a task would be more accurately and efficiently run by a machine (e.g. monitoring system states) or a person (e.g. decision making).

4.1 Categorising Human Failure

It is important to remember that human failures are not random; there are patterns to them. It is worth knowing about the different failure types because they have different causes and influencing factors and therefore the ways of preventing or reducing the failures are similarly different. There are two types of human failures (unsafe acts) that may lead to major accidents:

a. Unintentional errors:

Errors (slips/lapses) are "actions that were not as planned" (unintended actions). These can occur during a familiar task eg omissions like forgetting to do something, which are particularly relevant to repair, maintenance, calibration or testing. These are unlikely to be eliminated by training and need to be designed out.

Mistakes are also errors, but errors of judgement or decision-making ("intended actions are wrong") - where we do the wrong thing believing it to be right. These can appear in situations where behaviour is based on remembered rules or familiar procedures or unfamiliar situations where decisions ate formed from first principles and lead to misdiagnosis or miscalculations. Training is the key to avoid mistakes.

b. Intentional errors:

Violations differ from the above in that they are intentional (but usually well-meaning) failures, such as taking a short- cut or non-compliance with procedures e.g. deliberate deviations from the rules or procedures. They are rarely wilful (e.g. sabotage) and usually result from an intention to get the job done despite the consequences. Violations may be situational, routine, exceptional or malicious as outlined below

- Routine violations: a behaviour in opposition to a rule, procedure, or instruction that has become the normal way of behaving within the person's peer/work group.
- Exceptional violations: these violations are rare and happen only in unusual and circumstances, often when something goes wrong in unpredicted circumstances e.g. during an emergency.
- Situational violations: these violations occur as a result of factors dictated by the worker's immediate workspace or environment (physical or organisational).
- Acts of sabotage: these are self-explanatory although the causes are complex ranging from vandalism by a de-motivated employee to terrorism.

There are several ways to manage violations, including taking steps to increase their detection, ensuring that rules and procedures are relevant/practical and explaining the rationale behind certain rules.

Involving the workforce in drawing up rules increases their acceptance. Getting to the root cause of any violation is the key to understanding and, hence preventing the violation. The likelihood of these human failures is determined by the condition of a finite number of 'performing influencing factors', such as distraction, time pressure, workload, competence, morale, noise levels and communication systems. Given that these factors influencing human performance can be identified, assessed and managed, potential human failures can also be predicted and managed. In short, human failures are not random events.

The key message here is that human errors and rule breaking are largely predictable and therefore, can be identified and, most importantly, managed. We seek to encourage industry to tackle error reduction in a structured and proactive way, with as much rigour as the technical aspects of safety and make it an integrated part of their safety management system.

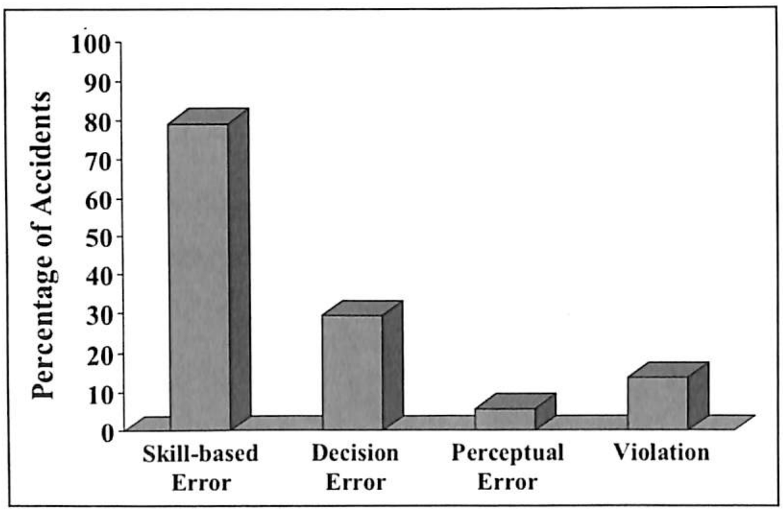

Figure 5: % of aircrew-related accidents by unsafe act category

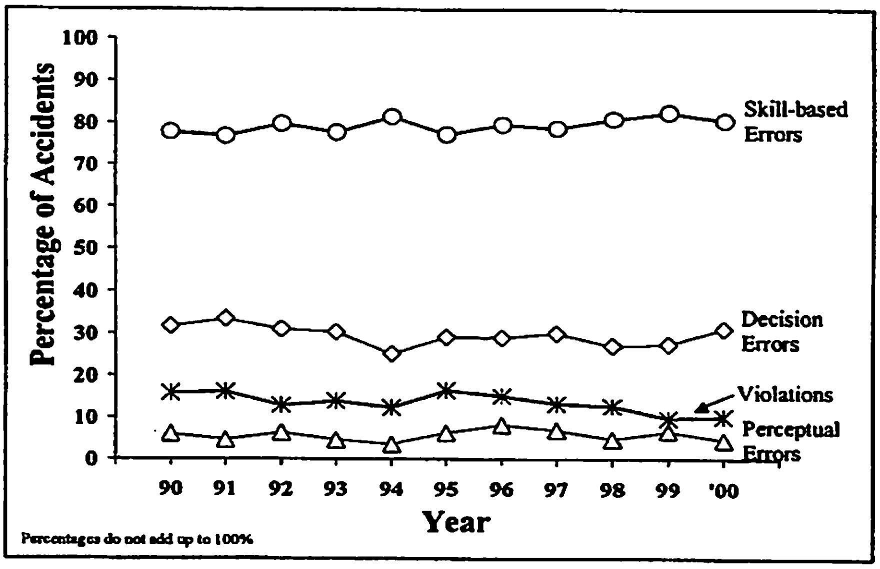

Figure 6: % of accidents by error category by year

Some Human Factors can pose significant risk but generally appear as symptoms of Human Factors that are more fundamental to human action. In this sense, Human Factors are layered. When it comes to using Human Factors in aviation safety management system such focus, and understanding are critical. As said before, Human Factors need to be understood as the human potential for risk, but also as the solution for adaptable and proactive risk management. The bureaucratic processes of aviation safety management system should be built up around Human Factors in order to empower employees rather than "treat the human problem."

4.2 The SHEL Model

It can be helpful to use a model to aid in the understanding of human factors, or as a framework around which human factors issues can be structured. A model which is often used is the SHEL model, a name derived from the initial letters of its components:

- **Software** (e.g. maintenance procedures, maintenance manuals, checklist layout, etc.);
- **Hardware** (e.g. tools, test equipment, the physical structure of aircraft, design of flight decks, positioning and operating sense of controls and instruments, etc.);
- **Environment** (e.g. physical environment such as conditions in the hangar, conditions on the line, etc. and work environment such as work patterns, management structures, public perception of the industry, etc.);
- **Livewire** (i.e. the person or people at the centre of the model, including maintenance engineers, supervisors, planners, managers, etc.).

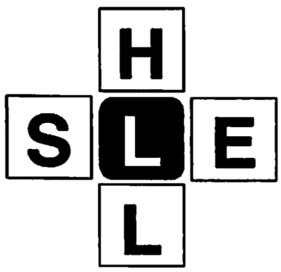

Figure 7: Shel Model

Human factors concentrate on the interfaces between the human (the 'L' in the centre box) and the other elements of the SHEL model (see *Figure 6.*) As man - the "Livewire" - can perform a wide range of activities. Even though modern aircraft are now designed to embody the latest self-test and diagnostic routines that modern computing power can provide, one aspect of aviation has not changed: tasks are still being done by human beings. However, man has limitations. Since

Livewire is at the centre of the model, all other aspects (Software, Hardware and Environment) must be designed or adapted to assist his performance and respect his limitations. If these two aspects are ignored, the human will not perform to the best of his abilities, may make errors, and may jeopardise safety.

Thanks to modern design and manufacturing, aircraft are becoming more and more reliable. However, it is not possible to re-design the human being: we have to accept the fact that the human being is intrinsically unreliable. However, we can work around that unreliability by providing good training, procedures, tools, duplicate inspections etc. We can also reduce the potential for error by improving aircraft design such that for example, it is physically impossible to reconnect something the wrong way around.

The list of human factors that can affect aviation maintenance and work performance is broad. They encompass a wide range of challenges that influence people very differently as humans do not all have the same capabilities, strengths, weaknesses, or limitations. Unfortunately, aviation maintenance tasks that do not account for the vast amount of human limitations can result in technical error and injuries. The below figure shows some of the human factors that affect aircraft maintenance personnel. Some are more serious than others but, in most cases, when you combine three or four of the factors, they create a problem that contributes to an accident or incident.

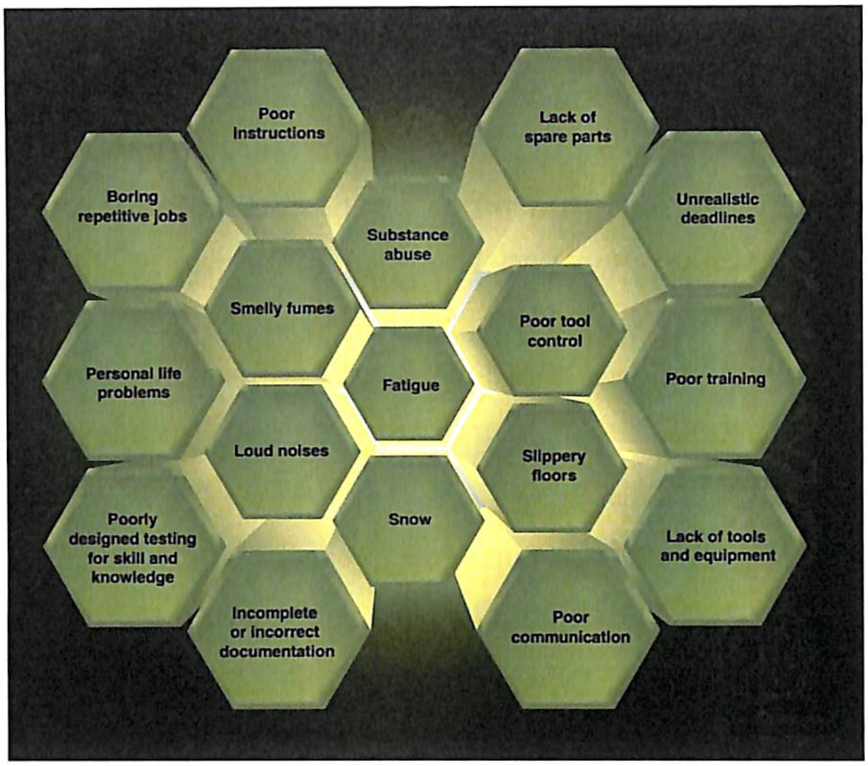

Figure 8: List of Human Factors in Aviation

4.3 Elements of Human Factors

Human factors are comprised of many disciplines. This section discusses ten of those disciplines: Clinical Psychology, Experimental Psychology, Anthropometrics, Computer Science, Cognitive Science, Safety Engineering, Medical Science, Organisational Psychology, Educational Psychology, and Industrial Engineering.

a. Clinical Psychology

Clinical psychology includes the study and application of psychology for the purpose of understanding, preventing, and relieving psychologically based distress or dysfunction and to promote subjective well-being and personal development. It focuses on the mental well-being of the individual. Clinical psychology can help individuals deal with stress, coping mechanisms for adverse situations, poor self-image, and accepting criticism from co-workers.

b. Experimental Psychology

Experimental psychology includes the study of a variety of basic behavioural processes, often in a laboratory environment. These processes may include learning, sensation, perception, human performance, motivation, memory, language, thinking, and communication, as well as the physiological processes underlying behaviours, such as eating, reading, and problem solving. To test the efficiency of work policies and procedures, experimental studies help measure performance, productivity, and deficiencies.

c. Anthropometrics

Anthropometry is the study of the dimensions and abilities of the human body. This is essential to aviation maintenance due to the environment and spaces that aircraft maintenance technicians have to work with. For example, a man who is 6 feet 3 inches and weighs 230 pounds may be required to fit into a small crawl space of an aircraft to conduct a repair. Another example is the size and weight of equipment and tools. Men and women are generally on two different spectrums of height and weight. Although both are equally capable of completing the same task with a high level of proficiency, someone who is smaller may be able to perform more efficiently with tools and equipment that is tailored to their size. In other words, one size does not f it all and the term "average person" does not apply when employing such a diverse group of people.

d. Computer Science

The technical definition for computer science is the study of the theoretical foundations of information and computation and of practical techniques for their implementation and application in computer systems. How this relates to aviation maintenance is a lot simpler. As mentioned earlier, aircraft maintenance technician spends as much time documenting repairs as they do perform them. It is important that they have computer workstation that are comfortable and reliable.

Software programs and computer-based test equipment should be easy to learn and use, and not intended only for those with a vast level of computer literacy.

e. Cognitive Science

Cognitive science is the interdisciplinary scientific study of minds as information processors. It includes research on how information is processed (in faculties such as perception, language, reasoning, and emotion), represented, and transformed in a nervous system or machine (e.g., computer). It spans many levels of analysis from low-level learning and decision mechanisms to high-level logic and planning. Aircraft maintenance technicians must possess a great ability to problem solve quickly and efficiently. They constantly must troubleshoot a situation and quickly react to it. This can be a viscous cycle creating an enormous amount of stress. The discipline of cognitive science helps us understand how to better assist technicians during situations that create high levels of stress so that their mental process does not get interrupted and effect their ability to work.

f. Safety Engineering

Safety engineering assures that a life-critical system behaves as needed even when the component fails. Ideally, safety engineers take an early design of a system, analyse it to find what faults can occur, and then propose safety requirements in design specifications up front and changes to existing systems to make the system safer. Safety cannot be stressed enough when it comes to aviation maintenance, and everyone deserves to work in a safe environment. Safety engineering plays a big role in the design of aviation maintenance facilities, storage containers for toxic materials, equipment used for heavy lifting, and floor designs to ensure no one slips, trips, or falls. In industrial work environments, the guidelines of the Occupational Safety and Health Administration (OSHA) are important.

g. Medical Science

Medicine is the science and art of healing. It encompasses a variety of health care practices evolved to maintain and restore health by the prevention and treatment of illness. Disposition and physical well-being are very important and directly correlated to human factors. Just like people come in many shapes and sizes, they also have very different reactions to situations due to body physiology, physical structures, and biomechanics.

h. Organisational Psychology

Organisational psychologists are concerned with relations between people and work. Their interests include organisational structure and organisational change, workers' productivity and job satisfaction, consumer behaviour, and the selection, placement, training, and development of personnel. Understanding organisational psychology helps aviation maintenance supervisors learn about the points listed below that, if exercised, can enhance the work environment and productivity.

i. Educational Psychology

Educational psychologists study how people learn and design the methods and materials used to educate people of all ages. Everyone learns differently and at a different pace. Supervisors should design blocks of instruction that relate to a wide variety of learning styles.

j. Industrial Engineering

Industrial engineering is the organised approach to the study of work. It is important for supervisors to set reasonable work standards that can be met and exceeded. Unrealistic work standards create unnecessary stressors that cause mistakes. It is also beneficial to have an efficient facility layout so that there is room to work. Clean and uncluttered environments enhance work performance. Another aspect of industrial engineering that helps in the understanding of human factors is the statistical analysis of work performance. Concrete data of work performance, whether good or bad, can show the contributing factors that may have been present when the work was done.

4.4 Murphy's Law

There is a tendency among human beings towards complacency. The belief that an accident will never happen to "me" or to "my Company" can be a major problem when attempting to convince individuals or organisations of the need to look at human factors issues, recognise risks and to implement improvements, rather than merely to pay 'lip-service' to human factors. "Murphy's Law" can be regarded as the notion: "If something can go wrong, it will." If everyone could be persuaded to acknowledge Murphy's Law, this might help overcome the "it will never happen to me" belief that many people hold. It is not true that accidents only happen to people who are irresponsible or 'sloppy'. The incidents and accidents described in paragraph 2. show that errors can be made by experienced, well-respected individuals and accidents can occur in organisations previously thought to be "safe".

Chapter 5: Interpretation of Results

If you think safety is expensive, try having an accident. These accidents create social influences and public perception to aviation accidents and airlines. When an accident happens, the media usually exaggerates the consequences and people may worry about airline safety management, resulting in loss of passengers and social panic. Even with the advancements in aeronautical technology and weather forecasting, aviation accidents still cannot be avoided. We still hear news about aircraft crashes, loss of control and disappearance due to human errors (e.g. pilot and maintenance error), bad weather, mechanical failure or sabotage. According to Aviation Safety Network, aviation accidents can be classified into accident, hijack, incident, other occurrence, untitled occurrence, write-off and hull-loss. Most aviation accidents are fatal, and involve other political problems, so it always causes huge public responses and concerns.

Human Factors is also a science. It is part of Aviation Psychology and many psychologists and flight safety experts are studying the effect of human factors in aviation. Aircraft is proven to be the safest among all transport modes, but why do they always cause a big social panic and have an influence on economic performances? Even though they are also rare, crash events are nearly always catastrophic. The aviation market is a highly competitive environment. The delivery of high-quality service to airline passengers is important for the airline's survival, competitiveness and sustained growth. Even though fatal aviation accidents are extremely rare, the rapid growth in aviation industries has caused increasing exposure to risk. Airlines need to understand what passengers expect in order to better serve their demands and achieve the highest level of satisfaction. Managing human failures is essential to prevent major accidents, occupational accidents and ill health, all of which can cost businesses money, reputation and potentially their continued existence.

5.1 Airline Safety Perception

Airline safety perception is controlled by several factors such as individual personal traits, cultural background, knowledge, diverse backgrounds, and the environment they are staying. Successful businesses achieve high productivity and quality while ensuring health and safety. Good technology combined with the best work systems can help to achieve these goals. The best work systems are based on having a skilled workforce, with well-designed jobs that are appropriate to individuals' abilities.

5.2 Health & Safety

The influence of biological, psychological and organisational factors on an individual at work can affect their health and safety, but it also affects their efficiency and productivity. For example,

- Someone needs to exert a large proportion of their strength to complete a task they are more likely to suffer injury and carry out the task inefficiently – possibly causing damage to the product and tools; or
- The mental demands of a task are too high, perhaps involving diagnosing faults under significant time pressures then there can be both a health issue for the employee but also a quality, and possibly safety issue for the production line, process and plant; or
- Individuals have very limited scope for determining how to do their job then they may lack motivation and job satisfaction and be less effective at work.

5.3 Ergonomics

Individuals have a wide range of abilities and limitations. A Human Factors (or Ergonomics) approach focuses on how to make the best use of these capabilities: by designing jobs and equipment which are fit for people. Advances in understanding human factors should be quickly applied to the key task of reducing the role of human errors in incidents and accidents, particularly about improving the situational awareness of operational personnel and improving the effectiveness of maintenance personnel.

Chapter 6: Conclusions and Scope for Future Work

In summary, the researcher's hypothesis for an urgent need for a more holistic and integrated approach to managing human factor errors in aviation industry is supported by this study. The overall goal of human factors is to support the attainment of high levels of human system performance across all aviation domains. It is recommended that aviation maintenance organisations adopt a human performance excellence mode to reduce the human factor errors in their organisations. Without a doubt, unless aviation maintenance organisations transform their people, processes and antiquated operational strategies, they will not succeed in eliminating the human factors errors from their organisations.

There are many areas that an aviation organisation can focus on and suggest that the key areas requiring improvement are, Leadership and Organisational Culture, Learning and Growth Measurement, Analysis and Knowledge Management and Process Management. It is highly recommended in expanding training and development in all areas. The most notable area is that of management training for managers and supervisors that will improve employees and labour relations. In general quality education and training are required in areas such as teamwork, shift management, culture diversity, communication skills and socialisation into organisations culture.

6.1 Recommendations

a. Conduction of Audits

Airline administrators should begin conducting audits in their own organisations, unless they will remain crippled by endless price wars and short-sighted cost cutting binges. Airline administrators must make the connection between what their external customers value and how and why employees provide that value and more. The bridge linking customer value to employee performance is human resource management. An audit constitutes both a reality check and a baseline from which to plan.

The national and international regulatory bodies in civil aviation should collaborate on formulating an airline-specific human resource management audit that could be readily adapted and used by individual airlines. An opportunity exists here for researchers in the field of human resource to conduct additional audits in the airline industry. Airlines should appoint a person whose responsibility it is to conduct timely employee opinion surveys on the following subjects: organisation culture, organisation leadership, employee relations, labour relations, equal opportunity employment and sexual harassment, and benefits preferences.

b. Training Management

Emphasis should be placed on communicating rules and regulations, and performance improvement and disciplinary procedures, be equalled or surpassed by the clear and ongoing communication to all employees of such things as the organisation's mission, strategy, and desired culture. This is a critical aspect of employee relations and labour relations. Most importantly training and development be greatly expanded upon. The most notable area is that of management training for managers and supervisors that will improve employee and labour relations. In general, however, greater education and training are required in such areas as teamwork, management, cultural diversity, communication skills and socialisation into the organisations culture. It is recommended that aviation maintenance organisations adopt a human performance excellence model to reduce, if not eradicate, the uptrend and spate of avoidable human factor errors in their organisations.

c. Adoption of Performance Excellence Framework

A major change that is required in these organisations is the reduction in time pressure imposed on their staff to complete maintenance jobs and tasks. Organisations that adopt a performance excellence framework should tailor the framework to their needs rather than implement the details of the framework lock-stock and barrel. Instead, organisations should fit their systems and processes into the framework and make changes where necessary. The key thrust for performance excellence is to establish a culture of continuous improvement and innovation that builds upon a strong foundation of quality, professionalism and team excellence, always. In order to establish a culture of excellence, organisational reviews cannot be restricted to certain areas of the aviation business such as safety and training. Reviews done in isolation underestimate the interdependency of several areas in a complex organisation such as the aviation industry. A framework to be proposed for an organisation to review its current health and the issues that require attention to prevent an incident or accident from occurring.

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