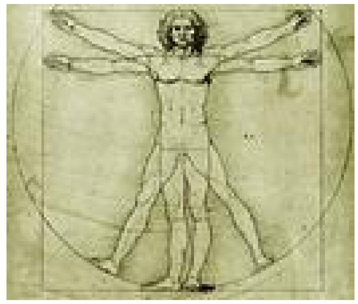
MANAGING HUMAN FACTORS IN AIRCRAFT MAINTENANCE THROUGH A PERFORMANCE EXCELLENCE FRAMEWORK



by

Adrian J. Xavier

A Graduate Research Project
Submitted to the Extended Campus
in Partial Fulfillment of the Requirements of the Degree of
Master of Aeronautical Science

Embry-Riddle Aeronautical University
Extended Campus
Hill AFB Resident Center
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This Graduate Research Project
was prepared under the direction of the candidate's Research Committee Member,
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approved by the Project Review Committee. It was submitted
to the Extended Campus in partial fulfillment of
the requirements for the degree of
Master of Aeronautical Science

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ABSTRACT

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Title: Managing Human Factors in Aircraft Maintenance through a Performance Excellence Framework.

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U.S. statistics indicate that 80% of aviation accidents are due to human errors with 50% due to maintenance human factor problems. 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 organizational effectiveness, organizational culture and personal learning and growth. A survey administered to a sample population of senior aviation maintainers in 18 countries revealed a consistent problem with aviation human factors and the need for a more integrated framework to manage human factor problems in aviation maintenance.

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CHAPTER I

INTRODUCTION

Background of the Problem

Imagine you are a member of an aviation organization, such as the military, and you have just been told that you will need to work over the weekend because there has been a fleet grounding issue on your F-16 aircraft. You will need to work to get all the aircraft inspected by Monday morning. You have just put in close to 60 hours of work that week and you are really tired. Your organization has sent you for Human Factors (HF) training and workshops and your management has told you to call for time-out when you feel tired yet they say there is an urgent need to get the aircraft inspected over the weekend. Although your body tells you that you can no longer take it, your mind tells you that you must keep going and be a team player or else the whole team will fail in this important mission. As you console yourself on your way home, you are reminded of how many times this year you have been doing this and the close encounters you have had with making an error of judgment. You are immediately reminded of that famous lecture you heard during HF training that "the chain is only as strong as its weakest link." The next morning, before you go to work, you hear that one of your friends the night before had hit and damaged the aircraft nose landing gear with a Harlan tractor and now management has called for an urgent safety briefing to remind everyone of the need to be vigilant and aware of such lapses in judgment. You immediately recall how one of your colleagues had been screaming to remove the Harlan tractor or Toyota tractor because they both had exactly the opposite reverse gears, in one you push the lever forward and the other backward. Does this sound far too familiar?

Today, more than ever, the aviation world is faced with the constant challenge of addressing human factors in maintenance. While there have been several advances to the study and implementation of human factors programs, there are still several inconsistencies to the way these programs are implemented and hence the varied results.

Aircraft maintenance work encompasses fast turnaround, high pressure with possibly hundreds of tasks being performed by large numbers of personnel on highly complex and technologically advanced systems in a confined area. It is very easy for information and tasks to fall through the safety net. Events around the world in the late 1970s, 1980s and early 1990s, involving crashes or serious accidents with aircraft, alerted the aviation world to the fact that although the aircraft were becoming much more reliable, the human being in the process had the potential to obliterate any of these technological advances. The role played by human performance can be found below.

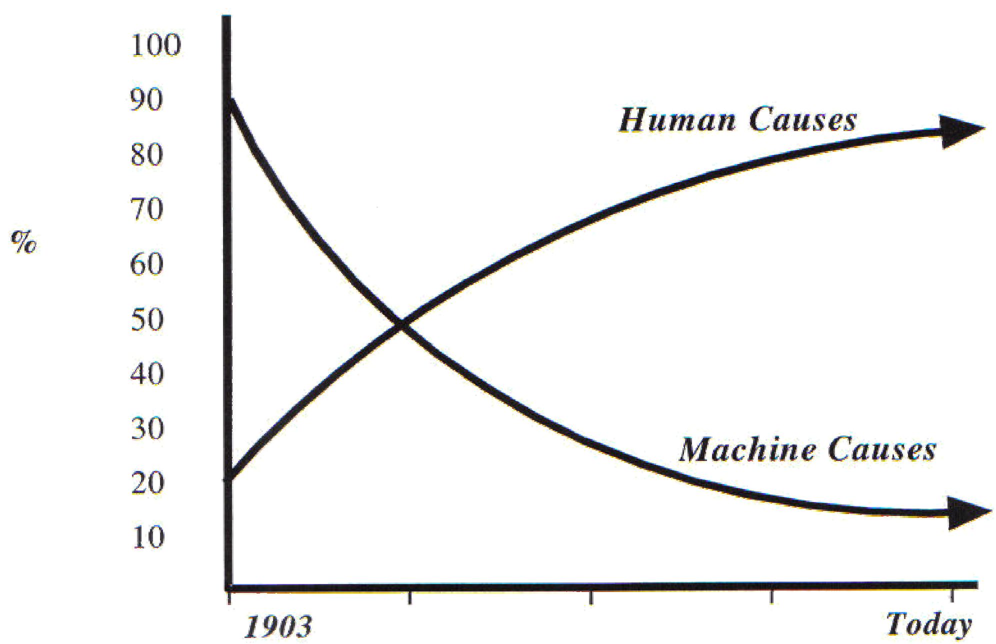


Figure 1: The role played by human performance in civil aircraft accidents.(IATA, 1975)

In this research project we will analyze the top human factor problems in aviation maintenance and evaluate a holistic solution to addressing these problems through a performance excellence framework. We will start with a brief look at the history of HF programs and the changes that have taken place over the years. We will also explore the current HF programs adopted by several organizations and try to understand why HF error occur, and how comprehensive, the solutions currently adopted. Then finally, we will look at the Baldridge national quality program and criteria for performance excellence to see if we can formulate a more comprehensive solution to managing HF in maintenance. In essence, we would be looking at a more systemic solution to HF management as HF is more than just about people.

Human Factors History

In the late 1970s, Cockpit Resource Management (CRM) featured prominently in pilot training. The term was used to apply to the process of training flight crews to reduce pilot error by making better use of the resources on the flight deck. A change in name was made from Cockpit to Crew Resource Management (CRM) to change the emphasis of training to focus on cockpit group dynamics. Some airline programs dealt with specific topics such as team building, briefing strategies, situational awareness and stress management. (Byrnes and Black, 1993). In the early 1990s, CRM training began to reflect the many factors, such as organizational culture, within the aviation system in which the crew must function which can determine safety.

Similarly, but much later, it was not until in the 90s that Maintenance Resource Management (MRM) was made available to maintenance personnel. After years of accidents, many caused by HF errors, nothing significant was really done to determine the HF root causes. Unlike CRM, MRM was very new to the aviation maintainers and it was not until June 10, 1990 when a cockpit window blew out at 16,000 feet, and a pilot almost went with it, that an in depth look at the contributing factors to a maintenance error were examined. (System Safety Services, 2000). David King, from the United Kingdom is one of the first to look at HF in the same light it is looked at today.

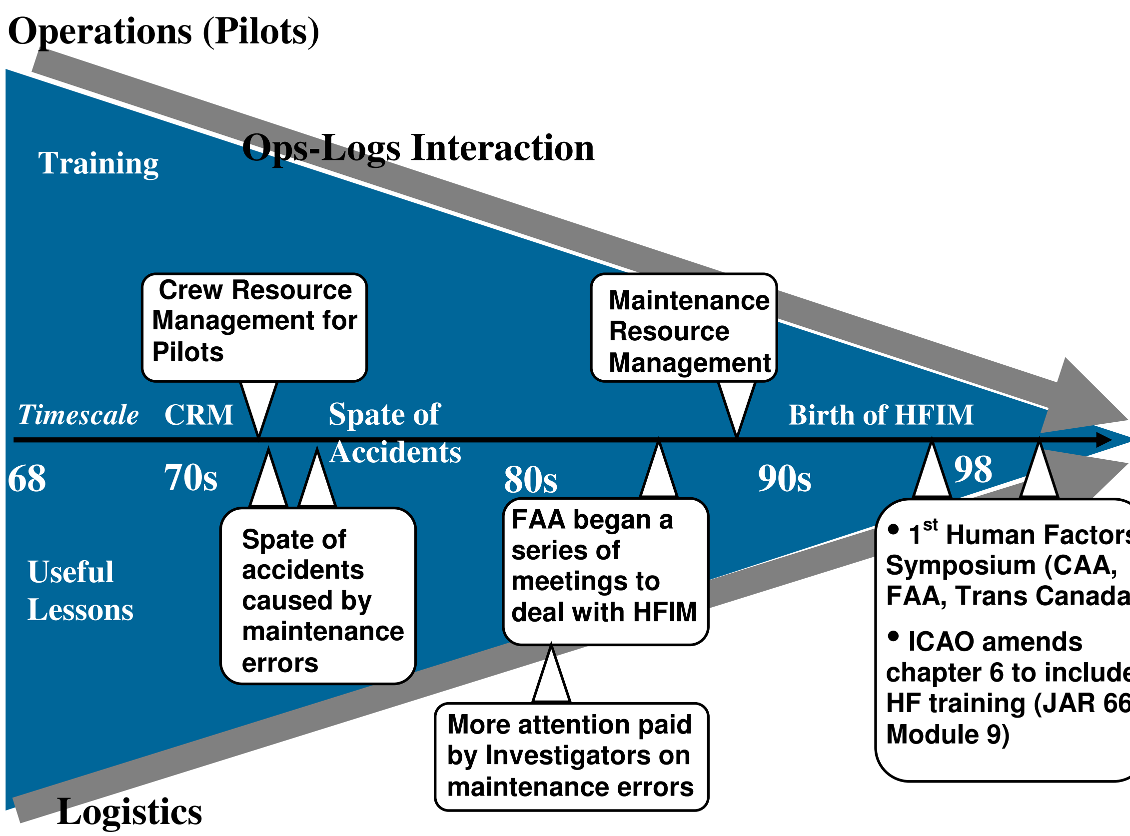


Figure 2: Human Factors History. *From Xavier.A , 2005.*

The need for a change in approach to human errors and their reporting was reinforced during the CAA sponsored 12th Symposium on Human Factors in Aviation Maintenance that was held in Gatwick Airport, England, on 10-12 March 1998. It was the first of the international symposiums involving the CAA, FAA and Transport Canada. The foundation of Human Factors training as a modern aviation tool was probably initiated in the United States at a workshop sponsored by the National Aeronautics and Space Administration (NASA) in 1979. This workshop was the development of NASA research into the causes of air transport accidents. The International Civil Aviation Organization, (ICAO) now requires organizations to include HFIM training. HF training which helps our fellow maintenance personnel to avoid an error he/she never intends to make had finally arrived (System, n.d).

Current Human Factor Programs in Aircraft Maintenance

MRM which later evolved into Human Factors in Maintenance (HFIM) was developed to provide primarily the training required to understand and prevent HF errors from occurring. The main breakthrough that was achieved in recent years is the emphasis given by senior management in organizations to HF programs. Many consultants and companies have enjoyed this upward focus on HF. Gordon Dupont, formerly of Transport Canada, is one such consultant whose excellent "Dirty Dozen" classification of HF root causes has been widely adopted by several aviation organizations. Other organizations like Boeing have developed their own in-house Maintenance Error and Decision Analysis (MEDA) programs with more in depth analysis including the background of personnel that commit these HF errors to better understand the extent of solutions necessary. Most of these programs are designed to identify the HF errors, educate the personnel on their causal potential, suggest ways to contain and correct the problem and create a HF error-free environment. While many of these programs have truly made the aviation work environment safer, many of them still look at HF from a 'people' perspective rather than "an organization" perspective. There may be a need to develop programs that improve the performance of all areas of an organization as a whole which will provide long term solutions to HFIM.

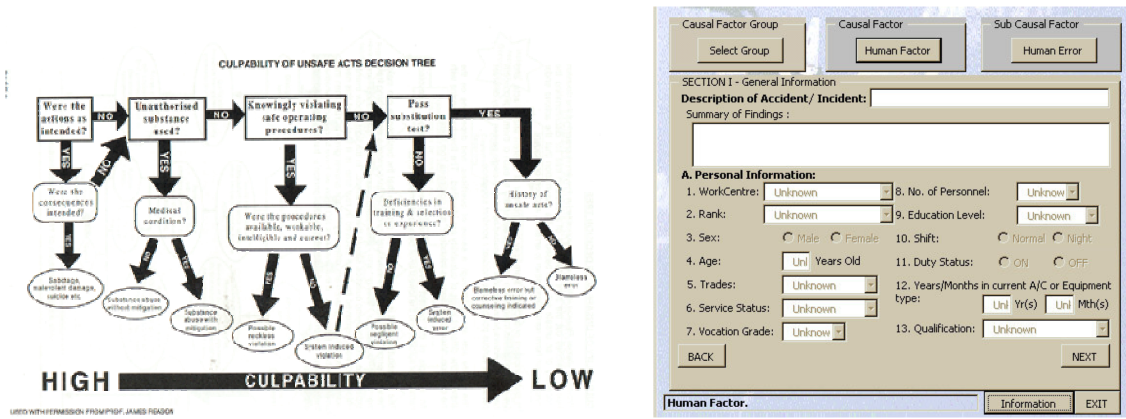


Figure 3: Maintenance Error Decision Aids. From SIA, 2000.

Performance Excellence Framework

Performance Excellence Framework (PEF) has been used in several countries and in several sectors such as Education, Healthcare, Tourism and Housing. Most recently, the Defense industry has been using such framework to gauge its quality health. One of the first of such frameworks, established in 1988, is the Malcom Baldridge National Quality Award (MBNQA) framework which covers all areas of a business such as Process Management, Information Management, Strategic Planning, Human Resource Development and the Use of Results (Hertz, 2004). 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.

Researcher's Work Setting and Role

The researcher has been an officer of the Republic of Singapore Air Force (RSAF) for 10 years. The researcher has held the equivalent rank of Major since 2001. The researcher has held positions as a deputy Officer Commanding Quality Assurance and a Flight Commander at an F-16 Air Force Base in Singapore. Currently the researcher is the Senior National Representative of the Republic of Singapore Air Force at the Ogden Air Logistics Centre (OO-ALC), Hill AFB, Utah. The researcher received his Bachelor of Engineering in Mechanical Engineering with specialization in Advanced Aerospace Materials from Bristol University, United Kingdom in 1995.

Statement of Problem

U.S. statistics indicate that 80% of aviation accidents are due to human errors with 50% due to maintenance human factor problems. Most programs currently implemented are designed to identify the HF errors, educate the personnel on their causal potential, suggest ways to contain and correct the problem and create a HF error-free environment. However, the percentage of HF errors in aviation mishaps is on the rise today. There is a need for a more integrated and holistic approach to HF management.

Limitations and Assumptions

Due to the limited funding and time, this researcher will limit the surveys to the Senior National Representatives (SNR) in OO-ALC/YPX to provide a summary of their countries perspectives on HFIM Management. Research results of the survey will be assumed to be representative of possible results from similar units within their respective Air Force.

CHAPTER II

REVIEW OF RELEVANT LITERATURE AND RESEARCH

Summary of Relevant Data

Human Factor Errors in Aircraft Maintenance Statistics

In the United Kingdom (UK) between 1982 and 1991, there were 1,270 Mandatory Occurrence Reports (MOR) which involved maintenance errors submitted to the CAA Safety Data Department (CAA, 1992). Of these, only 230 resulted in an unexpected or undesirable occurrence that interrupts normal operating procedures that may cause an accident or incident. The CAA concluded that there was no significant risk to the public. In the period 1992-1994, however, there were 230 MORs and in 1995 to 1996 there were 534. The number of reported errors was occurring at a greater frequency. Similarly a study by Boeing in 1993 of 122 occurrences between 1989 to 1991 revealed that 56% of human factors errors resulted in omissions with a further 30% resulting in incorrect installations.

In a field test by Boeing in 1994 to 1995 with nine maintenance organizations, the main types, causes and results of errors are summarized below (Boeing, 1996).

Table 1

Boeing field test with MEDA

1. Operational Events	2. Maintenance Error Types	3. Contributing Factors
3 Top Items :-		
Flight Delay (30%)	**Improper Installation (35%)**	**Information (50%)**
Aircraft Damage (23%)	**Improper testing (15%)**	**Communication (42%)**
Air Turn Back (15%)	**Improper servicing (12%)**	**Job/Task/Environment (40%)**

In 1998, the Australian Transport Safety Bureau (Hobbs & Williamson, 1998) surveyed close to 1400 Licensed Aircraft Maintenance Engineers (LAMEs). The most common outcomes for airline related maintenance occurrences were:

1. Systems operated unsafely during maintenance
2. Towing events
3. Incomplete installation

The most common outcomes of non-airline occurrences were:

1. Incorrect assembly or orientation
2. Incomplete installation
3. Persons contacting hazards

The most common causes to these unsafe acts are summarized below.

Table 2

1997 Survey by Australian Transportation Safety Bureau

Occurrence Causes and Contributory factors	Airline	Non-airline
Pressure	**21%**	**23%**
Fatigue	**13%**	**14%**
Coordination	**10%**	**11%**
Training	**10%**	**16%**
Supervision	**9%**	**10%**
Lack of Equipment	**8%**	**3%**
Environment	**5%**	**1%**
Poor Documentation	**5%**	**4%**
Poor procedure	**4%**	**4%**

A ground crew attitude survey in the military in Asia (classified source, n.d) revealed similar findings to that of the Australian Transport and Safety Board. The surveys were conducted bi-annually from 1999 to 2003 on approximately 2500 aviation technicians. In the survey conducted in 1999, the top three violations were:

1. Servicing without a checklist
2. Speeding
3. Omitting job steps

Approximately 20% of those surveyed disclosed that they would violate rules daily or once a week. The top three reasons for these violations were:

1. Too much work, too little time
2. Insufficient manpower
3. Time pressure to complete duties

In 2003, when the survey was conducted again, several key initiatives had been implemented to address HFIM such as :

1. Implementing a Human Factor training program initiated by Mr. Gordon Dupont, Chief Executive Officer (CEO), System Safety Services in 1999.
2. Training 100% of the licensed aircraft engineers in Human Factors Management.
3. Implementing a MEDA type Human Error Analysis Tool (HEAT).
4. Embracing a local version of the Malcom Baldridge Performance Excellence Framework for the military over six years from 1998.
5. Embracing additional performance excellence measurement tools such as the Balanced Score Card and Enhanced Value Organization principles.

The survey results comparison between 1999 and 2003 revealed the following significant improvements.

Table 3

Asian Study survey comparison between 1999 and 2003.

Survey Coverage	Results	
Safety Culture (new)	✓	**99% agreed that the organization placed strong emphasis on safety and quality. Personnel also agreed that management (96.43%), supervisors (97.30%) and personnel (94.38%) showed strong emphasis and take safety / quality seriously.**
Reasons for Violations	×	**Top 4 reasons remain unchanged. "Easy way out (taking short cuts)", which registered an increase of 11% (13% to 24%), has emerged as the 5th reason. "Lack of proper tools", the 6th reason, registered a significant increase of 14% (7% to 21%).**
Types of Violations	✓	**Overall reduction of 4% (14% to 10%) was noted for the 6 common types of violations observed everyday and once a week.**
Frequency of Violations	✓	**Improvement of 22% (21% to 43%) that violations observed were "very infrequent."**
Calling Timeout	✓	**Reduction by 11% (50% to 39%) in holding back to call timeout.**
Overtime Management	✓	**Reduction by 16% (49% to 33%) in frequency (weekly) of overtime.**
Open Reporting Culture	✓	**Improvement of 16% (66% to 82%) that open reporting is being practiced widely in the organization.**
Safety / Quality Information Dissemination	✓	**98% (an improvement of 8%) agreed that Safety/Quality information are readily available. Management are also conducting briefings and disseminating safety/quality information more frequently, matching closely to that desired in the previous survey.**

Several UK maintenance organizations have pooled their Maintenance Error Management System (MEMS) data, using a common MEDA taxonomy. The initial results were presented at a MEMS-MEDA seminar in the UK in May 2003, a selection of which is listed below.

Table 4

Several UK Maintenance Error Management System (MEMS) data

1. Improper Installation	**2. Improper Fault Isolation**	**3. Improper Servicing**
	3 Top Items :-	
Incomplete Installation	**System not Re/Deactivated**	**Service not performed**
Wrong Orientation	**Not properly tested**	**System not Re/Deactivated**
System not Re/Deactivated	**Not properly inspected**	**Insufficient fluid**
	3 Top Factors :-	
Individual performance factors	**Individual performance factors**	**Information**
Information	**Information**	**Communications**
Technical knowledge/Skills	**Communications**	**Individual performance factors**

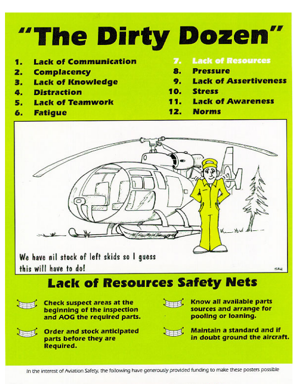
The maintenance error trends in US, Australia, Asia and United Kingdom from 1982 to 2003 are alarmingly similar and they continue to plague the aviation industry and in some areas of aviation such as in the military. The trends in maintenance human factor errors have continued to increase. A closer look at the statistics indicate that these trends are due mainly to lapses in the organizational operational culture and business processes. Time pressure seems to be the main factor due to lack of manpower and excess workload. In recent years, HF training has focused on these lapses in rules and the detrimental consequences of such actions. There is still an uptrend of these maintenance errors and violations in the aviation maintenance field.

Current Human Factor Programs in Aircraft Maintenance

Several HFIM courses have evolved since ICAO required HFIM training which include those by the UK CAA, FAA as well as JAR compliant courses to ensure consistency and conformance to minimum standards set out by the governing bodies. A typical HFIM course such as the one developed to comply with JAR145-12 includes:

1. A General introduction to Human Factors
2. Safety Culture/Organizational factors overview
3. Human Performance, limitations and Human Error models
4. Environmental issues impacting Human Performance
5. Procedures, Information, Tools and Practices
6. Professionalism, Integrity, Communication and Teamwork
7. Organization HF program including the management of HF errors

Gordon Dupont, formerly from Transport Canada, now CEO of System Safety Services, is a renowned human factors proponent and conducts several of his HPIM courses all around the world in the aviation sectors. He is best known for his "Dirty Dozen" posters which depict the most common 12 human factor errors in maintenance.



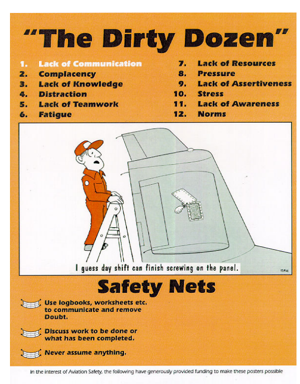


Figure 4: "The Dirty Dozen." From Gordon Dupont, System Safety Services.

Gordon conducts three workshops, HPIM Part One to Part Three, and covers areas such as the background to HFIM behaviors and errors through case studies, organizational culture and risk management and ways to manage them.

As can be seen from the typical course structures above, current HFIM courses generally adopt the three E's or Educate personnel, Equip personnel with the tools necessary to contain, correct and prevent HF errors and Evaluate the management of HFIM programs. This in essence is the main coverage for most HFIM courses and programs adopted by commercial airline and other aviation industries.

Professor James Reason and his "Swiss Cheese" model propounds that there are several latent conditions prior to an active failure or unsafe act. These failed or absent defenses line up to cause a mishap or injury waiting to happen. Interestingly, one of the first lapses in defenses in his model starts at organizational influences as can be seen from the model below. Gordon Dupont, CEO, System Safety Services modified James Reason's "Swiss Cheese model" incorporating his famous "Dirty Dozen" human error factors as the preconditions to unsafe acts which could eventually cause an accident/incident. Gordon attributes 70% of accident causation to fallible decisions by management, deficiencies in line management and the preconditions which are the "Dirty Dozen" human error factors. (G. Dupont, n.d)

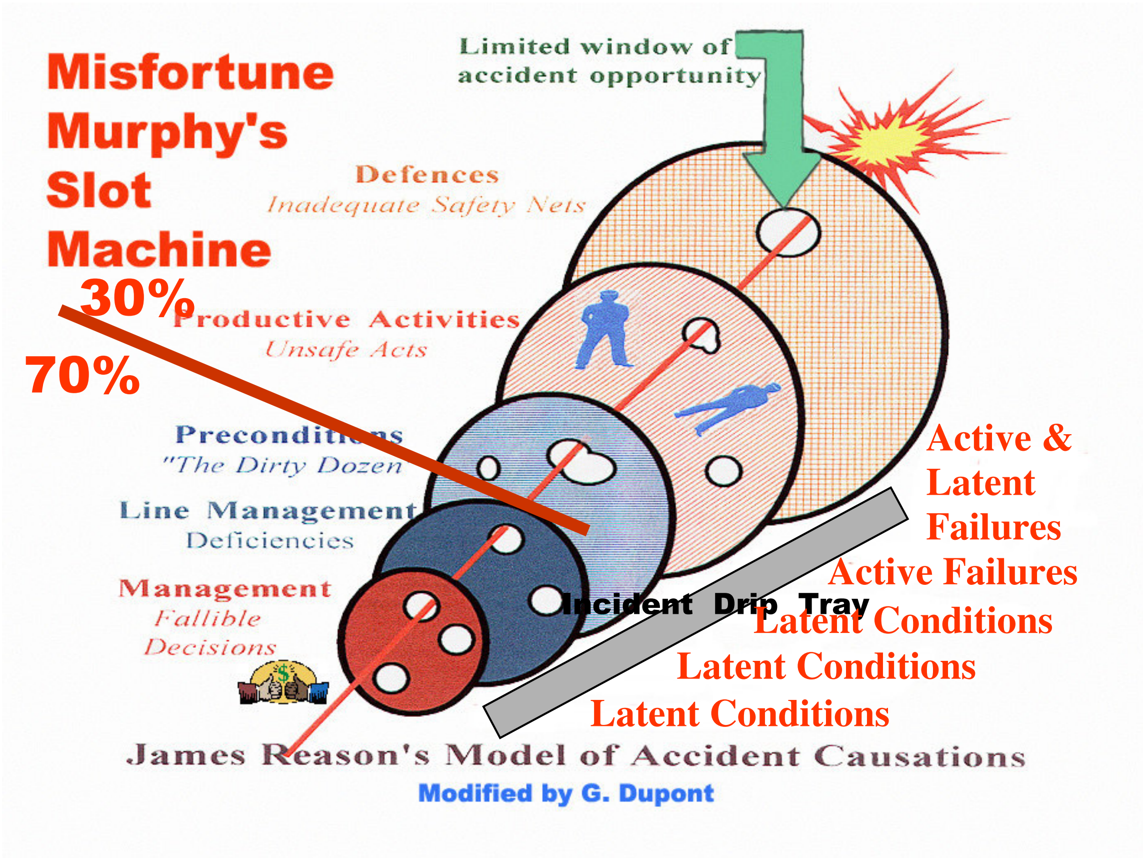


Figure 5: Misfortune Muphy's Slot Machine. James Reason's Model of Accident Causation modified by G. Dupont.

Aviation Performance Excellence Framework

More than 66 business excellence awards in 43 countries have been established adopting similar frameworks to the MBNQA framework. One of the many objectives of this framework is to create the values desired by businesses and customers and build a system which can sustain a competitive edge for an extended period of time. Most of these performance excellence frameworks have seven main criteria areas namely:

1. Leadership
2. Strategic Planning
3. Measurement, Analysis and Knowledge Management

4. Human Resource Focus
5. Process Management
6. Customer and Market Focus
7. Business Results

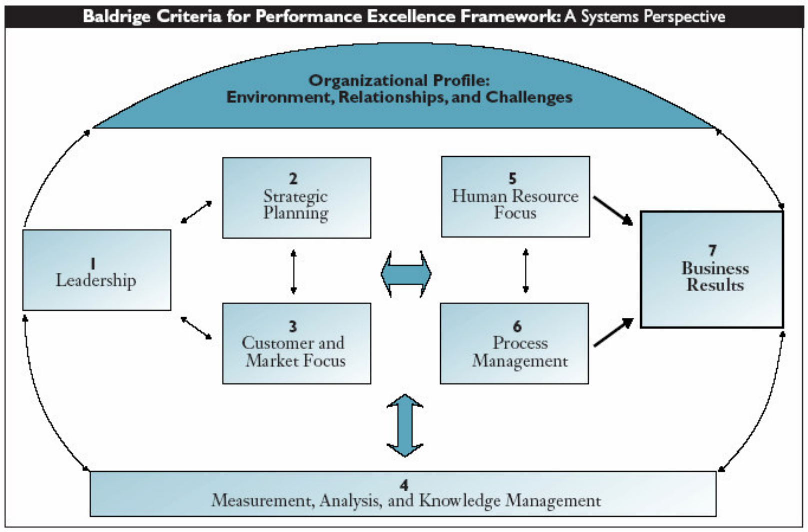


Figure 6: MBNQA Criteria for Performance Excellence Framework

One of the main objectives of the framework criteria is to motivate an organization into creating strategies, systems and methods of achieving excellence, stimulating innovation and building knowledge and capabilities. Achieving the highest levels of business performance requires a well-executed approach to organizational and personal learning. This will result in not only better products but also move toward being more responsive, adaptive, innovative and efficient thus giving an organization marketplace sustainability and performance advantages while it gives employees the satisfaction and motivation to excel (Hertz, 2004).

Today, the main focus in many businesses is the relentless pursuit for innovation. Innovation means making meaningful change to improve an organization's products, services and processes and to create a new value for the organization. Organizations should be led and managed so that innovation becomes part and parcel of the learning culture and is integrated into daily work. The use of a balanced composite of leading and lagging performance indicators measures the effective means to communicate short and long term priorities. It also helps monitor performance and provides a clear basis for improving results. The adoption of this framework constitutes a systemic approach to managing an organization and is proposed in this paper as a necessary means for reducing significantly aviation's "Dirty Dozen" maintenance human factor issues. Several defense related organizations have adopted this framework and tailored it to their needs. Some of the key realigned objectives from the framework can be found below. The MBNQA framework has been adopted by many sectors in the industry namely health, education and most recently in the defense industry in Asia over the last 10 years. The framework provides excellent criteria for organizations to follow to permeate a culture of excellence. Most relevant for the defense industry, and to human factor management, are the four main areas of the framework namely:

1. Leadership and Organizational Culture
2. Measurement, Analysis and Knowledge Management
3. Human Resource Focus
4. Process Management

The key objectives for the Malcom Baldridge National Quality Award framework for performance excellence can be translated to key objectives for a successful Human Factor program.

Statement of Research Question

Since the dawn of aviation, the aviation maintenance community has been constantly motivated to reduce human factor errors and its operational/organizational impact. Most programs currently implemented are designed to identify the HF errors, educate the personnel on their causal potential, suggest ways to contain and correct the problem and create a HF error-free environment. While many of these programs have truly made the aviation work environment safer, human factor errors still continue to persist today. There is a need for a more integrated and holistic approach to human factor management.

CHAPTER III

RESEARCH METHODOLOGY

Research Design

The research design used for this study was the self-report descriptive research method. A quantitative descriptive approach will be used to collect and assess the data. Survey results were the sole source of data collection for this study.

Research Model

The researcher has collected a wealth of HFIM data and results from organizations in Asia, Australia and the United States to understand the current state of HFIM and the initiatives currently implemented. The researcher used a survey that will be e-mailed to 25 OO-ALC/YPX Senior National Representatives (SNR) representing close to 18 countries with military ranks ranging from Major to Brigadier General at Hill AFB. The survey was administered to ascertain the effectiveness of human factor management through various programs and initiatives adopted.

Survey Population

The survey population for this study is 25 SNRs. The sample population for this study is 25 SNRs assigned to the OO-ALC/YP, which is located at Hill Air Force Base, Utah. The SNRs with ranks from Major – Brigadier General represent 18 countries namely :

1. FMS countries – Pakistan, Oman, Korea, Greece, Thailand, Israel, Turkey, Italy, Singapore, Venezuela, Taiwan and Egypt .
2. EPAF (European participating) countries – Belgium, Norway, Holland, Denmark, Portugal and Germany.

Table 5

Survey Demography

Overall			
Participation by Countries			
		Senior National Representatives	
Total (R) =	**25**	**FMS countries (x)**	**European countries (y)**
Total Participants (TP) =	**24**	**16/17**	**6/8**
Participation Rate = ($^{TP}/_{R}$)%	**96%**		
Participation by Countries = (x&y/$_{TP}$) %		**94.1%**	**75.0%**

Participation by Appointment & Years of Service					
			Years of Service (z)		
Management	**16**	**65.2%**	**z < 10 years**	**10 ≤ z < 15 years**	**z > 20 years**
Technicians	**8**	**34.8%**			
No. of participants by Yr of Service (YS) =			**3**	**7**	**14**
Participation by Yr of Service = ($^{YS}/_{TP}$) %			**12.5%**	**29.2%**	**58.3%**

Source of Data

The sources of data was a combination of completed research from organizations such as NTSB, FAA, Boeing and military organizations as well as a data collection device in the form of a survey. The survey were e-mailed to the SNRs of OO-ALC/YP.

Pilot Study

A pilot survey was presented to the researcher’s Embry-Riddle Aeronautical University MAS 605 classmates. The survey sample for this study was 15 personnel with varied background such as maintenance, administration and contracts. Invaluable feedback was given by the classmates on the researcher’s use of terms, flow of questions in the questionnaire as well as the clarity of certain feedback surveyed.

The Data Gathering Device

The data gathering device used in this study was a researcher designed survey. The survey included questions to determine the rank, job description, seniority, total length of military service, HFIM awareness and nine questions designed to determine the implementation and effectiveness of HFIM programs. The researcher consulted the opinion of several renowned HFIM activists and organizations on the details of questions in the survey. The researcher also consulted the Behavioral Science department of his native country on the design of the survey.

Table 6

Survey coverage and objectives

Survey Coverage	Objectives
Human Factors Program	To find out if the surveyed representative has a Structured HFIM program in their organization.
	To find out how long the HFIM program has been in existence
	If HFIM program is not existent, then to find out if it is important to have one.
Human Factor Management	To find out if the Human Factor programs currently implemented have improved HF errors in the organization
	To find if the training and tools currently available is sufficient to manage HFIM errors.
	To find out if More needs to be done to manage HFIM errors in maintenance
Most common outcomes of Safety occurrences	To find out what are the most common outcomes of HFIM safety occurrences
	To find out the most likely reason for these outcomes
	To find out the areas needed to be managed better to reduce HFIM errors.

Distribution Method

The HF survey was written as a word document and e-mailed to the personnel assigned to OO-ALC/YPX. The researcher met with the SNRs personally prior to sending out the survey so as to notify them of such an effort. The researcher also met with the SNRs to go through the survey and clarify each question as required. The researcher also took the opportunity to gather personal feedback from senior officers on their experiences with human factor issues. SNRs were given one week to review the questions. All responses were collected back by the researcher at a stipulated time.

Instrument Reliability

This researcher's Embry-Riddle Aeronautical University MAS 605 classmates conducted a peer review of the HFIM management Survey which gave the researcher good feedback on the reliability of the survey. Upon completion of the survey on the SNRs, the researcher conducted a stability or test-retest reliability analysis.

Instrument Validity

This researcher's Embry-Riddle Aeronautical University MAS 605 classmates conducted a peer review of the HFIM management Survey. Additionally, the researcher consulted several experts in the field of Human Factor management such as those from Boeing, NASA and a human factors in maintenance "guru", Mr. Gordon Dupont, on the survey structure and contents. Each question was reviewed to evaluate the relevancy to the purpose. The results of the survey were collected, and the researcher was able to validate the accuracy of the measurement instrument.

Treatment of Data and Procedures

Because the researcher surveyed two groups of people, namely those with extensive maintenance experience and those with only a few years of experience, he reviewed the results of the survey by experience level. As the survey population was too small, the researcher omitted using statistical analysis tools such as the Spearman correlation analysis to review the influence of years of maintenance experience on the management of human factors. The data gathered from the HFIM management surveys were analyzed to determine the effectiveness of HFIM programs. The researcher will then made conclusions and recommendations based on these data.

CHAPTER IV

RESULTS

The results of the Human Factor Management Survey carried out from December 2004 to January 2005 can be found below. Of the survey population, 96% was sampled. The results are broken down to the four parts of the survey questionnaire. The survey can be found in Appendix B.

Human Factor Programs and Management

Of the countries surveyed, 66.6% have a structured Human Factors Maintenance Program. Of these countries that have a structured program, 80% have had it for

Table 7

Human Factors Management Survey

Human Factors Survey (%)	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**
There is a **structured** HFIM program in your organization?	20.8	45.8	25.0	8.3
	66.6		**33.3**	
In yes, how **many years** has it been in existence?	> 10 years	5-10 years		< 5 years
	53.3	26.6		20.0
If no, it is **important** to have one?	100	0	0	0
	100		**0**	
HFIM programs implemented have **improved** the management of human factors errors in your organization?	20.8	50.0	20.8	8.3
	70.8		**29.1**	
Training and tools currently available in your organization are **sufficient** to manage HFIM?	12.5	41.6	41.6	4.1
	54.1		**45.7**	
More needs to be done to manage HFIM errors in maintenance?	70.8	25.0	4.1	0
	95.8		**4.1**	

more than five years. Most countries agree that the programs in their organizations have improved human factor error management. The responses on the effectiveness of tools and training to manage human factor errors in maintenance were mixed in that 54% thought they were adequate while 45% thought otherwise. However, a good majority, or **95.8%** of those surveyed clearly felt that ***"More needs to be done to manage HFIM Errors".***

Most Common Outcomes of Safety Occurrences

The most common outcome of HFIM safety occurrences were "System operated unsafely during maintenance". This was followed closely by "Incorrect assembly or orientation of part". More than 50% of those surveyed thought that these were the Top two outcomes of safety occurrences in their organization.

Table 8

Most common Outcomes of Safety Occurrences

In your opinion, which of these are the most common outcomes of HFIM safety occurrences? ***Please select 1 or more that are the most common outcomes for this section***		
POS	**Outcomes**	**%**
1	**System operated unsafely during maintenance**	**62.5**
2	**Incorrect assembly or orientation of part**	**50.0**
3	**Part/aircraft damaged during repair**	**33.3**
4	**Tool lost on aircraft/in maintenance facility**	**29.0**
5	**Material left on aircraft**	**26.6**
6	**Injury to personnel**	**25.0**

"Pressure" was the top most likely reason for the occurrence of safety violations. "Pressure" together with the "Lack of Training" were the two top reasons for safety violations.

Table 9

Most common reasons for the occurrence of the outcomes

The most likely reason for the occurrence of these outcomes? ***Please select 1 or more that are the most common outcomes for this section***		
POS	**Outcomes**	**%**
1	**Pressure**	**62.5**
2	**Lack of Training**	**50.0**
3	**Fatigue**	**45.8**
4	**Supervision**	**41.6**
5	**Lack of Equipment**	**12.5**
6	**Environment**	**12.5**

In the opinion of those surveyed, more than 50% listed the "Attitudes of Personnel", "Training Effectiveness" and "Organizational Culture" as the top factors that need to be reviewed to better manage human factor errors in maintenance.

Table 10

Top HFIM drivers that need reviewing

In your opinion, HFIM errors can be managed better by reviewing….? ***Please select 1 or more that are the most common outcomes for this section***		
POS	**Outcomes**	**%**
1	**Attitudes of personnel**	**58.3**
2	**Training Effectiveness**	**54.1**
3	**Organizational Culture**	**50.0**
4	**Processes**	**33.3**
5	**Leadership**	**33.3**
6	**Management of Information**	**25.0**

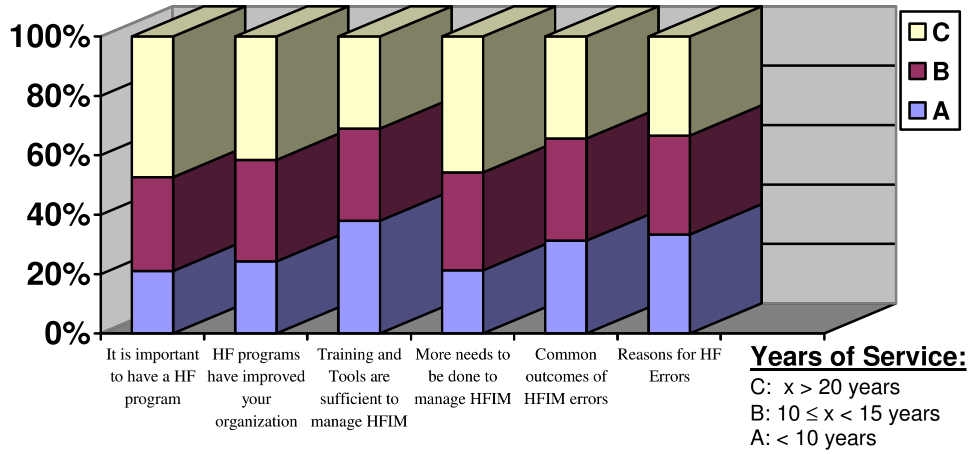


Figure 7: Influence of experience on human factor management survey.

Comparison of the survey answers by experience level revealed very little differences in the answers and agreement levels between the three bands of experience levels surveyed.

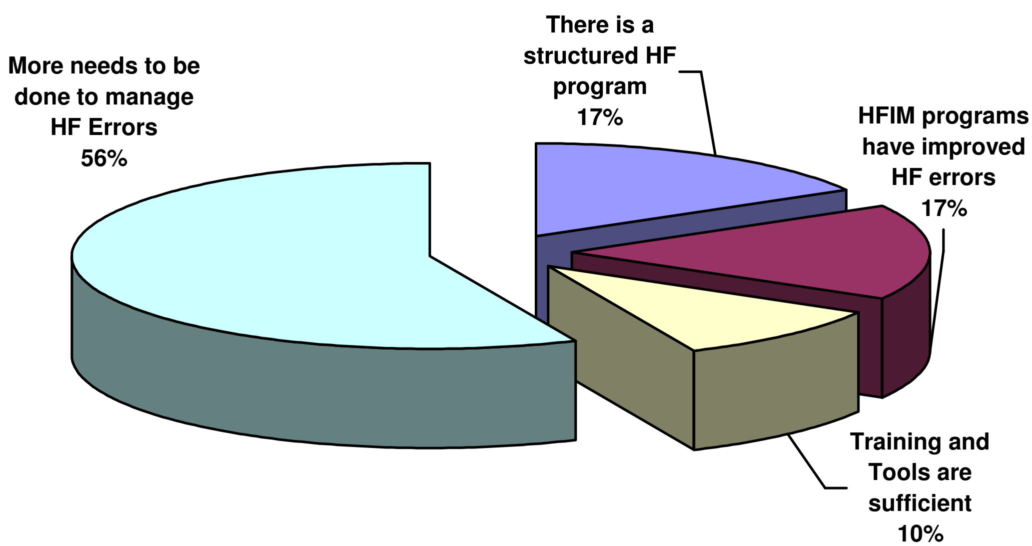


Figure 8: Breakdown of results of those who "strongly agree" that they have a structured HFIM program.

Of those surveyed, 17% “strongly agreed” that they had a structured HF program and that the program was showing improvements to HF management. Also, 56% “strongly agreed” that more was needed to be done to improve the HFIM program.

Survey Feedback

Several senior officers that were surveyed, most of whom had been maintenance commanders in their previous appointment, had very good comments and feedback during the survey. Some of these comments were :

1. *The main issue in my opinion is “complacency”. A lot is due to repeated jobs over and over. Not paying attention to the little details.*
2. *Managers and Supervisors need to be more patient when shops get a lot of work. Most mistakes are made when technicians get interrupted during their tasks to do other jobs and feel pressure to always get done quickly. The T.Os are usually very good; it’s the amount and variety of different tasks that causes problems. It is hard to do tasks that may be quite complicated when you are always in a rush.*
3. *To improve or reduce HFIM management/errors you need:*
   - b. *Effective implementation of supervisory training*
   - c. *Timely sharing of information(incidents/accidents)*
   - d. *Motivation at all levels*
   - e. *Involvement of leaders and supervisors with the subordinates*

4. Personnel should be trained and watched by supervisors to make sure they are gaining an understanding of correct processes and staying to the procedures. Personal opinions as to how a job should be done should be eliminated, in favor of closely following pre-established procedures.

5. I think that the lack of pressure and fatigue are special human error producer. I think generally, the air forces have to consider a rest time for technicians just like the rest time valid for crew members.

6. Most common outcome is repeat/recurring of present malfunction due to lack of efficient maintenance procedures related to HFIM.

b. The first thing that maintenance leaders/managers and maintainers must believe is in the necessity and help of the HFIM concept.

c. The most important is psychological factors (i.e wants, expectations, attitudes and motivation) then next comes human sensory factors and physiological factors.

d. As a 16 years aircraft maintenance officer to me the most problematic area for HFIM management in aircraft maintenance are:

i. Norms of the maintenance people

ii. Night shifts (you'd better check the effectiveness of shifts and their change over consequences in A/C maintenance)

CHAPTER V

DISCUSSION

While many research studies in the past have been done mainly on airline organizations, this research study on military organizations has shown consistent results with those studies in the last 20 years. The management survey conducted on senior maintenance officers and specialists from the Air Forces of 18 countries revealed very consistent findings thus far on the management of HF errors in maintenance.

1. Human Factor Management Programs

It was very comforting to note that many (80%) of the organizations surveyed had implemented a structured human factor program for at least five years now with a good proportion (70.8%) of them seeing improvements from these programs. This is a testament to the focus and attention given by all major aviation agencies such as the FAA, NTSB, CAA, ASTB, JAA on the need for educating and evaluating aviation maintainers on the nature and detriment of human factors. Close to 60% of those surveyed had more than 20 years of maintenance management experience and yet their expert views on the management of human factors in maintenance were very consistent even with those who were in service for only a few years. Even those who strongly agreed that their organizations had a structured HF program, and that the programs implemented had improved the management of HF errors, strongly felt (56%) that more was needed to be done to manage HFIM errors in maintenance.

2. Most Common Outcomes of Safety Occurrences

The top three common reasons for the occurrence of safety outcomes which are "pressure" (62.5%) , "lack of training" (50.0%) and "fatigue" (45.8%) seem to be the clear catalysts for the most common outcomes which are “system operated unsafely during maintenance”(62.5%) and “incorrect assembly or orientation of parts” (50.0%). Although aviation operations are high, operational tempo environments, the ‘pressure’ factor has consistently been the main influencing factor for human factor errors for the last 20 years. Some of the reasons for “pressure” could be due to lack of training, tools, equipment or just the attitude of the personnel or organizational culture. Many people have different eustress levels which is the stress level that allows them to perform optimally. As such, job matching and training needs analysis are vital to ensuring organizations have the right people at the right place at the right job.

3. Top HFIM drivers that need reviewing

While the top three drivers for human factor errors were “attitudes of personnel”(58.3%), “training effectiveness” (54.1%) and “organizational culture”(50.0%), the remaining three factors were just as contributory namely, ‘processes’, leadership and ‘management of information’. These six factors are so varied that one can only conclude that it is clearly the view of those surveyed that there is a need for an extensive review of an organization to eradicate human factor errors. Even those surveyed who “strongly agreed”(20.8%) that they had a structured HF program, and that the program was improving the management of human factor errors, felt that “more was needed to be done to manage human factor errors” (56.6%).

4. Influence of experience on human factor management

There were three categories of those surveyed, namely, those with less than ten years of experience, between 10 and 20 years of experience and those with more than 20 years of experience in their respective organizations. The results of the survey shows that the experience level had little or no effect on the views of current human factor management programs, that is, even those with a few years of experience had similar responses to the effectiveness of human factor management and the types of errors it produced.

It was evident in the comments and feedback given by the senior officers at the end of the survey, as well as personally to me during our discussions, that the three main areas they see as contributory to errors occurring in the workplace were:

1. Complacency
2. Distraction
3. Not following proper procedures

These contributory human factors support the results of the most common safety outcomes derived from the survey. These factors are similar to what the "Dirty Dozen" factors by Mr.Gordon Dupont warn us to take note of daily in aviation maintenance.

The Asian study from 1999 to 2003, after implementing several new initiatives and a performance excellence framework similar to the MBNQA framework, reaped several significant results such as a 50% reduction in human factor errors and in many others such as these:

1. Safety Culture.

This was a new segment of questions that surveyed on the safety and quality culture at the various levels, e.g. from the organization level down to individuals. Results showed that 99.01% (51.02% = Strongly Agree; 47.99% = Agree) of personnel agreed that the organization placed strong emphasis on safety and quality. Similarly, personnel also agreed that management (96.43%), supervisors (97.30%) and personnel (94.38%) also showed strong emphasis and take safety and quality seriously.

2. A good safety and quality culture is due to the many years of strong and continual safety and quality emphasis at the various staff and command levels, coupled with the comprehensive safety and quality programs and initiatives implemented at the various levels as part of the performance excellence framework reviews.

3. Reasons for Violations.

The top four reasons remained unchanged, i.e. "Time pressure to complete task", "Too much work, too little time," "Insufficient manpower" and "Unrealistic requirements from management." Among the top four reasons, "Unrealistic requirements from management" registered a 9% drop (35% to 26%), whereas "Time pressure to complete task," "Too much work, too little time," "Insufficient manpower" increased by 10%, 11% and 5% respectively.

4. The increase in percentages for the top three reasons for violations correlated with the increase in ops tempo and requirements, especially after the 911

accident, where more standby requirements were put in place and more peacetime contingencies were activated.

5. Types of Violations.

The results showed an overall improvement of 4% for the six common types of violations observed everyday and once a week. Analysis was also done by examining whether there were any adverse trend by specific units or by specific group of personnel (years of service). The results showed that there was no specific trend.

6. Frequency of Violations.

There was an across-the-board reduction in the frequency of violations being observed, particularly, a significant reduction of 100% was noted for "Very Infrequent," from 21% to 43%. Slight improvements were also noted for "Everyday" (5% to 4%) and "Once a week" (9% to 6%).

7. Calling Time-Out.

The results showed an overall drop of 11% (50% to 39%) in holding back to call time-out, with an across-the-board drop in all the concerns. "Fear of being labeled as lazy" registered a significant drop of 23%. These results showed that calling time-out is slowly gaining acceptance.

8. Analysis revealed that the length of service played a part in the willingness of personnel to call time-out. The more senior personnel concerns were "Do not wish to 'let down' supervisors or management" and "Worry for not meeting ops requirements." This is not surprising because they are the group who holds the

responsibilities to ensure that the work is completed on time. Though it shows that they are committed, it must not be overdone. A balance must be struck, or else it would create unnecessary pressure on the junior to hold back on calling time-out when the real need arises. This effect was indeed reflected by the junior as one of their concerns was "Fear that supervisors are not supporting for calling time-out." Other reasons include "Pressure from colleagues," "Fear of being labeled as lazy" and "Manpower shortage."

9. Over-Time (OT) Management.

The results showed a 16% reduction in the frequency of OT done weekly. This is most likely contributed by the following:

a. A 6% reduction of "Unrealistic requirements from management
b. Better (3% improvement) co-ordination among multi-trade rectification.
c. Lesser (45% improvement) waiting time (<2 hours) between jobs
d. Better (3% improvement) time management of personnel.
e. Lesser (8% lesser) secondary duties.
f. 11% increase in "Easy way out (taking short cuts)".

10. Open Reporting.

Open reporting is a concept of reporting those minor/major incidents that did not result in damage or anything clearly visible to management or your peers but yet can contribute significantly when shared amongst peers so as to create a culture of sharing and learning. The open reporting concept has, over the years, encouraged people from reporting mistakes/incidents without the fear of being punished. Although there was a 6% drop on "Open reporting is well accepted in the organization" to 84%, the willingness to open report has improved. Fourty percent of personnel held back from open reporting due to "Uncertainty of what the consequences would be" if they open report.

CHAPTER VI

CONCLUSION

In summary, the researcher's hypothesis for an urgent need for a more holistic and integrated approach to managing human factor errors in maintenance is supported by this study. The researcher recommends a performance excellence framework, like the MBNQA framework, be adopted to review the organizations people, processes and results. The solutions adopted today, in terms of organizational reviews and human factor training, have been done in isolation and not as an integrated review of the entire organization. The results from the Asian study from 1999 to 2003, reported in this study, supports the researcher's hypothesis and proposed solution to the problem.

Many experts believe and this study supports the argument, that there has to be a transformation. Without a doubt, unless aviation maintenance organizations transform their people, processes and antiquated operational strategies, they will not succeed in elminiating the "Dirty Dozen" from their organizations.

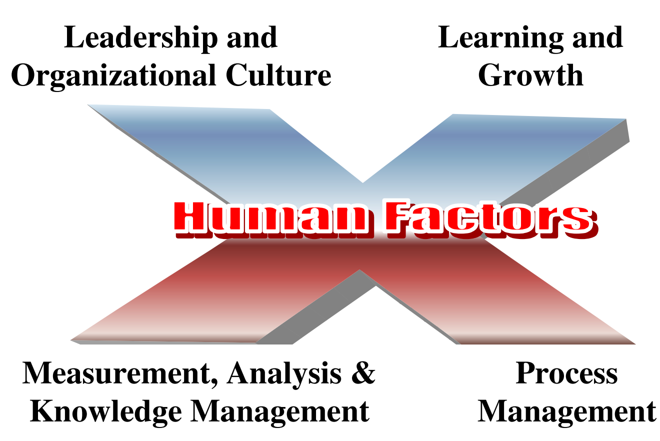


Figure 9 : Human Performance X'cellence Model. A.Xavier 2005.

CHAPTER VII

RECOMMENDATION

Based on the results of the survey, and the downward trends from the Asian study between 1999 and 2003 , it is recommended that aviation maintenance organizatiomns adopt a human performance excellence model like the MBNQA framework to reduce, if not eradicate, the uptrend and spate of avoidable human factor errors in their organizations. There are many areas that an organization can focus on but results of surveys in the last 20-30 years suggest that the key areas requiring improvement are:

1. Leadership and Organizational Culture
2. Learning and Growth
3. Measurement, Analysis and Knowledge Management
4. Process Management

A major change that is required in these organizations is the reduction in time pressure imposed on their staff to complete maintenance jobs and tasks. Organizations 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, organizations 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.

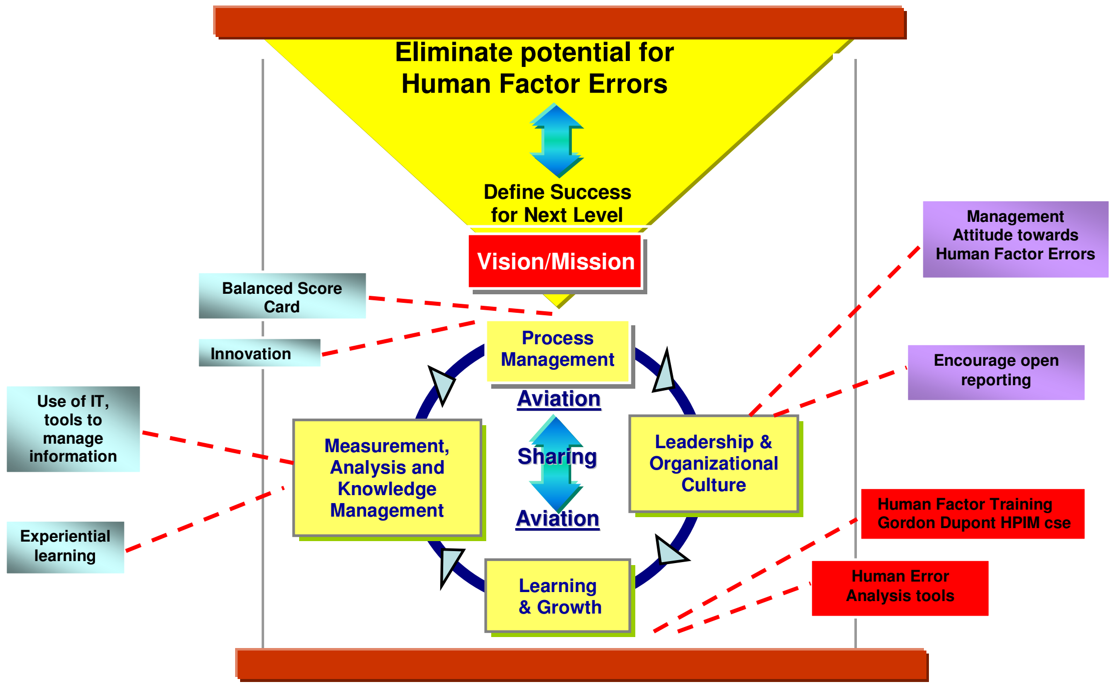


Figure 10: Human Performance Excellence Model. A. Xavier 2005.

In order to establish a culture of excellence, organizational 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 organization such as the aviation industry. A framework such as the one proposed in the tables that follow, provide the over-arching framework for an organization to review its current health and the issues that require attention to prevent an incident or accident from occurring.

Table 11

Performance Excellence Framework in relation to HFIM

Criteria	**Objectives**	**HFIM relation**
Leadership And Organizational Culture	• How senior executives develop, communicate and demonstrate the purpose, vision and goals for the organization that focus on Safety/Quality. • How the organization translates these values into policies, practices and behavior. • How the organization permeates a culture consistent with it's values • How the organization overcomes any difference between The current culture and the desired culture	+ Human Factor goals, targets. + Management view on errors. + Open reporting, tools for data collection. + Training, rewards, feedback + Surveys, process reviews, crisis teams to review organization
Measurement, Analysis and Knowledge management	• How information needed to drive day to day management and improvements to organizations performance is selected and managed. • List key types of information and describe how they are related to organizations performance objectives & goals • How the organization ensures information is reliable, accessible and disseminated quickly to employees and external parties. • How the organization evaluates and improves it's management of information How comparative and benchmarking information is selected to improve the organizations performance.	+ Key performance indicators for Safety must be selected and managed + Create a database of cases and incident/accidents and measure it's effect such as cost of a HF error etc. + Accessibility of database and sharing of lessons learnt to prevent a re/occurrence through meetings/forums etc + Implementation of safety information system + Benchmark accident statistics and do comparative studies with leading companies

Table 11 (continued)

Performance Excellence Framework in relation to HFIM

Criteria	**Objectives**	**Human Factor relation**
Learning & Growth	• Describe the organizations human resource requirements and plans, based on the organizations strategic objectives and plans	+Manpower levels with relation to task levels.Training, rewards, staff performance management and recognition.
	• How the organization implements and reviews it's human resource plans	+ Deployment of personnel based on needs, recognition system and constant review based on complexities of tasks
	• Mechanism available to encourage employee involvement and commitment to teamwork, innovation and the achievement of the organizations goals and objectives.	+ Implementation of cross functional/project mgt teams, innovations efforts to improve work environment.
	• How the organization identifies and reviews it's education, training and development needs to support it's goals and objectives	+Training needs analysis, management system, review based on HFIM trends/cases. Interviews with staff on their needs
	• How the organizations employee performance and recognition systems support it's objectives and goals	+Morale of employees, task saturation, promotion and rewards.
Process Manage-ment	• The organization has a systematic process to acquire, evaluate and implement creative ideas	+Safety improvements, process changes
	• The organization's key processes have clear objectives and targets	+Is safety one of the key processes?
	• The organization has a system to analyse root causes , take prompt corrective action and prevent future occurrence when a process fails to meet specified standards or targets.	+Safety Management system that tracks and follow-ups on safety findings
	• There are various methods to access the quality and performance of the organization's key business processes	+Audits/inspections and feedback channel
	• The organization has a systematic approach to act on the results of the various assessments conducted on key processes.	+Committee/program/track follow-up actions

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APPENDIX A

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APPENDIX B

Terms, Definition and Acronyms

AFB	Air Force Base
CAA	Civilian Aviation Authority
CEO	Chief Executive Officer
CRM	Crew Resource Management
FAA	Federal Aviation Authority
HF	Human Factors
HEAT	Human Error Analysis Tool
HFIM	Human Factors in Maintenance
HPIM	Human Performance in Maintenance
GURU	One who is widely acknowledged as an expert in his field
IATA	International Air Transportation Association
ICAO	International Committee for Aviation Organizations
JAR	Joint Aviation Regulations
LAMEs	Licensed Aircraft Maintenance Engineers
MBNQA	Malcom Baldridge National Quality Award
MEDA	Maintenance Error and Decision Analysis
MEMS	Maintenance Resource Management
NASA	National Aeronautics and Space Administration
NTSB	National Transportation and Safety Board
OO-ALC	Ogden Air Logistics Centre, Hill AFB
PEF	Performance Excellence Framework

RSAF	Republic of Singapore Air Force
SNR	Senior National Representatives
UK	United Kingdom

APPENDIX C

DATA COLLECTION DEVICE

HUMAN FACTORS MANAGEMENT SURVEY

My name is Adrian Xavier and I am working towards fulfilling my requirements for a Master in Aeronautical Science Degree from Embry-Riddle Aeronautical University. One of my degree requirements is the completion of a Graduate Research Project. This survey is the research instrument used to gather data for this project. Your assistance in completing this survey will provide invaluable, anonymous data pertinent to this research topic.

Thank you for your time and help. If you would like an executive summary of my findings, please provide your name and address below (your personal information will not be used nor reflected in my report):

Name: ____

Address: ____

____

Adrian J. Xavier

HUMAN FACTORS MANAGEMENT SURVEY

PERSONAL DETAILS

Name: ***(Optional)***		***Years in organization :***	**> 20 years** ○ **10-15 years** ○ **< 10 years** ○	***Job Description:***	
Rank:		***HFIM Awareness***	**Poor** ○ **Average** ○ **Good** ○ **Excellent** ○	***Involved in Maintenance?***	Y/N

Human Factors (HF) Fact:

U.S. statistics indicate that 80% of aviation accidents are due to human errors with 50% due to maintenance human factor problems. Most programs currently implemented are designed to identify the HF errors, educate the personnel on their causal potential, suggest ways to contain and correct the problem; and create a HF error-free environment. However, HFIM errors are still on the rise today.

	Please mark your response in boxes Strongly agree → Strongly disagree					
	6	5	4	3	2	1
1. Human Factors Programs						
1.1 There is a structured Human Factors Program in your Maintenance organization?						
1.2 If yes, how many years has it been in existence?	○ > 10 years		○ 5-10 years		○ < 5 years	
1.3 If no, is it important to have one?						
2. Human Factors Management						
2.1 The HFIM programs currently implemented have improved the management of human factor errors in your organization?						
2.2 The training and tools currently available in your organization are sufficient to manage HFIM?						
2.3 More needs to be done to manage HFIM errors in maintenance?						

3. Most Common Outcome of Safety Occurrences (check all that apply)

3.1 In your opinion, which of these are the most common outcomes of HFIM safety occurrences?

- ○ Incorrect assembly or orientation of part
- ○ Injury to personnel
- ○ Tool lost on aircraft / in maintenance facility
- ○ Part/aircraft damaged during repair
- ○ Material left on aircraft
- ○ System operated unsafely during maintenance

3.2 The most likely reason for the occurrence of these outcomes

- ○ Pressure
- ○ Fatigue
- ○ Lack of training
- ○ Supervision
- ○ Lack of equipment
- ○ Environment

3.3 In your opinion, HFIM errors can be managed better by reviewing it's

- ○ Leadership
- ○ Processes
- ○ Management of information
- ○ Organizational culture (not just safety)
- ○ Attitudes of personnel
- ○ Training effectiveness

4. Do you have any additional comments or suggestions to improve or reduce HFIM management/errors?

____

Thank You for your valuable input.