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# Human Factors Digest No. 15

## Human Factors in Cabin Safety

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# FOREWORD

Safety of the civil aviation system is the major objective of ICAO. Considerable progress has been made, but additional improvements are needed and can be achieved. It has long been known that less than optimum human performance underlies the majority of aviation accidents and incidents, indicating that any advance in this field will have a significant impact on the improvement of aviation safety.

This was recognized by the ICAO Assembly, which in 1986 adopted Resolution A26-9 on Flight Safety and Human Factors. As a follow-up to the Assembly Resolution, the Air Navigation Commission formulated the following objective for the task:

> To improve safety in aviation by making States more aware and responsive to the importance of human factors in civil aviation operations through the provision of practical human factors material and measures developed on the basis of experience in States, and by developing and recommending appropriate amendments to existing materials in Annexes and other documents with regard to the role of human factors in the present and future operational environments. Special emphasis will be directed to the human factors issues that may influence the design, transition and in-service use of the [future] ICAO CNS/ATM systems.

One of the methods chosen to implement Assembly Resolution A26-9 is the publication of guidance materials, including manuals and a series of digests, which address various aspects of Human Factors and their impact on aviation safety. These documents are intended primarily for use by States to increase the awareness of their personnel on the influence of human performance on safety.

The target audience of Human Factors manuals and digests is the managers of both civil aviation administrations and the airline industry, including airline safety, training and operational managers. The target audience also includes regulatory bodies, safety and investigation agencies and training establishments, as well as senior and middle, non-operational airline management.

This digest is an introduction to the latest information available to the international aviation community on relevant Human Factors considerations for aircraft passenger cabin safety.

## OVERVIEW

Chapter 1 describes how cabin crew training is geared towards the development of emerging competencies in support of the establishment and maintenance of high team performance standards. This has been achieved with the development of a CRM-based team approach to solving complex operational problems.

Chapter 2 addresses the fact that critical safety briefings are usually ignored by passengers. The safety briefings content and procedures need to be enhanced to optimize their potential safety benefit.

Chapter 3 presents the numerous issues surrounding aircraft exit and evacuation. There are several aspects of aircraft exit and evacuation that can help mitigate the risk of severe injuries. The completion of a safe evacuation is highly dependent on the usability of safety equipment. It also depends on a relevant Human Factors aspect which is the competent management of passenger behaviour (e.g. disruptive passengers) for the safety of others. Disruptive, competitive behaviours have been reported in studies of evacuations with monetary incentives and in accident reports where evacuations have taken place during a cabin fire.

Chapter 4 highlights several central organizational considerations, such as culture, policy development and implementation, and error management, all of which directly impact the attainment of operational objectives. These organizational factors need to be carefully considered so that they can support a human-centred safety and security culture throughout an organization. A brief overview of error management elements is also presented.

Appendix A lists Annexes to the Convention on International Civil Aviation that include Human Factors Standards and Recommended Practices. Appendix B describes human strength limits in the creation of design guides. Appendix C provides information on Human Factors audit elements for cabin crew training. Appendix D contains the Bibliography.

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# INTRODUCTION

## GENERAL

1. The broad application of Human Factors knowledge contributes to decreasing accidents and incidents in civil aviation as well as to mitigating the impact of those accidents and incidents. Human Factors knowledge can be applied to cover the myriad interactions among people, technology, organizations, cultures and the environment. Increasing awareness of the importance of Human Factors in civil aviation and the application of its principles presents the international civil aviation community with a significant opportunity to make it both safer and more efficient.

2. ICAO has been proactively pursuing this objective and introduced Human Factors in the training and licensing requirements of Annex 1 (1989) and in the operation of aircraft requirements of Annex 6 (1995). In addition, largely through the work of the ICAO Flight Safety and Human Factors Programme, the awareness of Human Factors opportunities and challenges present in civil aviation has increased steadily and markedly across the international civil aviation community since 1990.

## DEFINITION OF HUMAN FACTORS

3. The human element is the most flexible, adaptable and valuable part of the civil aviation system, but it is also the most vulnerable to influences that can adversely affect its performance. With the majority of accidents and incidents in the civil aviation system resulting from less than optimal system performance, there has been a tendency to attribute them to human error. However, the term "human error" is of little use in accident prevention and mitigation. Although it may indicate where in the system the breakdown occurred, it provides little indication as to why it occurred. An error attributed to the human component of the system may have been design-induced or associated with inadequate or inappropriate training, badly designed or implemented procedures, or a poor layout of checklists or manuals (see the *Human Factors Guidelines for Safety Audits Manual* (Doc 9806)). In contemporary safety thinking, human error is the starting point rather than the end point in accident prevention and mitigation.

> Human Factors is concerned with people in their dynamic working environments; about their diverse relationships with the technological elements, with procedures, and with the environment of the civil aviation system; and also with their relationships with other people. These include human behaviour; decision-making and other cognitive (i.e., mental) processes; the design, learnability, maintainability, and usability of controls and displays; flight deck and cabin layouts; communication and software aspects of computers, maps, charts and documentation such as aircraft operating manuals, standard operating procedures, checklists, etc.

## A FRAMEWORK OF HUMAN FACTORS

4. Given the multi-faceted nature of Human Factors, it is helpful to use a framework in the description and understanding of Human Factors concepts. One such basic framework, the SHEL, uses blocks to represent some of the different components of Human Factors. The SHEL framework (see Figure 1) with the name being derived from the initial letters of its fours components: Software, Hardware, Environment and Liveware was first

developed by Edwards (1972) and later modified by Hawkins (1987). Each component of the SHEL framework represents one of the building blocks of Human Factors. The following interpretations are suggested: Liveware (human), Hardware (technology), Software (policies, procedures, processes) and Environment (situation and culture within which the L-H-S interactions occur).

5. The liveware, or the human element, is the centrepiece of the framework representing the most critical and flexible component. This component does have limitations most of which are predictable in general terms.

6. Errors in human performance are cited as causal or contributory factors in the majority of civil aviation accidents and incidents. Experience has shown that most incidents and accidents that occur in operational environments are not due to the catastrophic failure of single components within a system but to the mismatches at the interfaces of different system elements. Thus, while it is possible for a crew member to suffer a sudden and complete incapacitation, or for a hardware element in the system to fail with disastrous results, it is far more likely for errors causing incidents and accidents to arise from individuals and errors in the system. From the perspective of dealing with unsafe conditions, errors arise from the incorrect allocation of tasks due to poorly designed procedures.

## LIVEWARE — THE INDIVIDUAL

7. The core of the model is comprised of human operators, the most flexible and critical component in the system. However, humans are subject to considerable variations in behaviour and performance limitations that are predictable in general terms. The limits of the human component in the system are not clearly delineated, so the other components of the system must be carefully matched to it if stress in the system and eventual break-down are to be avoided. Modifications through Human Factors need to start with the identification of where mismatches between components exist and contribute to an accident or incident.

8. In order to optimize matching components, an understanding of the characteristics of the central component is essential. Some of the more important characteristics (Hawkins, 1975) are described as follows:

- *Physical size and shape*. In the design of most equipment, a vital role is played by body measurements and movements, which will vary as a function of age, ethnicity and gender groups. The data for such design decisions are available from anthropometry and biomechanics.

- *Physical needs*. Humans' requirements for food, water and oxygen are available from physiology and biology.

- *Input characteristics*. Humans have evolved a sensory system for processing information from the world around them, enabling them to respond to external events in completing goal-directed behaviour. But all senses are subject to degradation and error, and the relevant sources of knowledge are available from physiology, psychology and biology.

- *Information processing*. These human functions have limitations. Poor instrument, warning system and interface design have frequently resulted from a failure to take into account the capabilities and limitations of the human information system.

- *Output characteristics*. Once information is sensed and processed, messages are sent to the muscles to initiate the desired response, whether it be a physical control movement or the initiation of some form of communication. Acceptable control forces and direction of movement must be known, and biomechanics, physiology and psychology provide such knowledge.

- *Environmental tolerances*. Temperature, pressure, humidity, noise, time of day, light and darkness all impact performance levels and well-being.

9. The interfaces among the different system components must be thought out carefully.

**Human-technology interactions (liveware-hardware (L-H) interface)**

10. This interface is the one most commonly considered when speaking of human-machine systems: designs of seats to fit the characteristics of the human body, of displays to match the sensory and information-processing capabilities of the user, of controls with proper movement and low force requirements, coding and location. The human operator may never be aware of a deficiency in the liveware-hardware (L-H) interface, even when it may lead to an accident, because the human operator can adapt to L-H mismatches masking any deficiencies, but cannot remove its existence.

**Human-procedures interactions (liveware-software (L-S) interface)**

11. This reflects the relationship between the individual and supporting systems found in the workplace. It can span subjects such as regulations, policies, standard operating procedures (SOPs) and processes, which include manuals, checklists, publications, symbology and instructions.

**Human-human interactions (liveware-liveware (L-L) interface)**

12. This is the interface between people. Cabin crew, flight crew, air traffic controllers, maintenance engineers and other operational personnel function as teams, and team influences play a significant role in determining behaviour and performance. In this interface, we are concerned with leadership, crew coordination and cooperation, teamwork, attitudes and cultural diversity interactions. Staff and management are also within the scope of this interface, as organizational culture, corporate climate and operational constraints can significantly affect human performance.

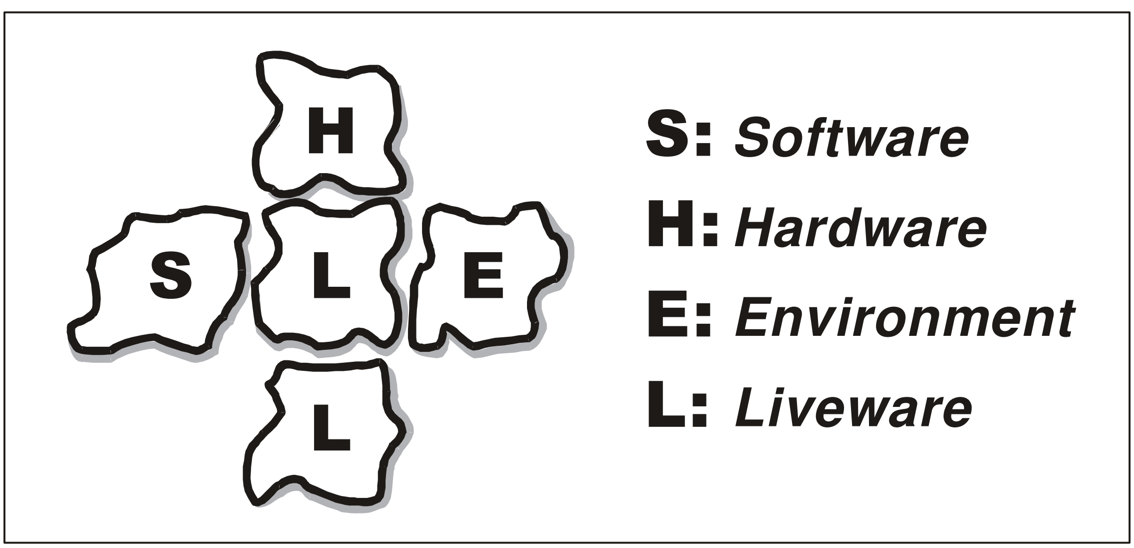


**Figure 1. Graphical representation of the SHEL framework (Hawkins, 1987)**

### Human-environment interactions (liveware-environment (L-E) interface)

13. This interface involves the relationship between the individual and both the internal and external environments. The internal workplace environment includes such environmental factors as temperature, ambient light, noise, vibration and air quality. The external environment (for pilots) includes such things as visibility, turbulence, terrain and illusions. Increasingly, the work environment for flight crews includes disturbances to normal biological rhythms such as disrupted sleep patterns. Since the aviation system operates within a context of broad political and economic constraints, which in turn affect the overall corporate environment, such factors as the adequacy of physical facilities and supporting infrastructure, the local financial situation and regulatory effectiveness are included here. While the crew's immediate work environment may be creating pressures to take shortcuts, inadequate infrastructure support may also compromise the quality of crew decision-making.

### Human error

14. Human error is cited as being a causal or contributing factor in the majority of aviation occurrences. All too often these errors are committed by highly trained, qualified, experienced (i.e. skilled) and motivated personnel. Human error is a natural outcome of output from the human brain that uses predefined scripts and other shortcuts to complete goal-oriented behaviours. These shortcuts sometimes lead to errors.

15. Errors may be the consequence of either intentional or unintentional behaviour. They may be further subdivided into slips, lapses and mistakes depending on the degree of intention preceding them.

- *Slips* are unintentional actions where there is a lack of appropriate attention (inattention or overattention) due to distractions, misordering of sequences or mistiming of actions.

- *Lapses* are unintentional actions where there is a memory failure due to forgetting an intention, losing one's place or omitting planned items.

- *Mistakes* are intentional actions resulting from errors in planning, but there is no deliberate decision to contravene established rules or procedures. Mistakes are based on the application of rules drawn from our knowledge; they may result from the application of a rule that, while good, is inappropriate for the current situation, or from the application of a flawed rule.

16. Slips and lapses are essentially automatic responses with little, if any, conscious decision-making — they are errors in execution. On the other hand, mistakes involve deliberate decision-making and evaluation based on knowledge, experience and mental models that have worked well in the past — they are errors in planning.

- *Violations* are related to mistakes. Although slips, lapses and mistakes may all lead to technical breaches of regulations or company operating policies and procedures, they are considered to be errors since they are not based on a deliberate decision to contravene the established rules. Like mistakes, violations involve intentional planning, often based on knowledge and the mental model acquired through daily experience; but violations are deliberate decisions to contravene established rules or procedures and are often a result of having to adapt procedures.

17. As presented earlier, within the SHEL framework the irregular surfaces on the various elements depict the imperfect matches in interfacing humans with the other elements of their environment. Therefore, each of the imperfectly matched interfaces has a potential for initiating or exacerbating errors, for example:

- In the human-technology interactions, knobs and levers that are poorly located or lack the proper coding may create confusion leading to slips or mistakes.

- In the human-procedures interactions, delays and errors may occur while seeking vital information from confusing, misleading or cluttered documentation, leading to slips or mistakes.

- At the human-environment interface, environmental factors (e.g. noise, temperature, lighting and vibration) or a disturbance in biological rhythms may affect an individual's attention and response levels, the ability to reason or communicate, and attitude towards fellow crew members and the flight itself, any of which could facilitate slips, lapses or mistakes.

- Poor human-human interactions at all levels of the system may reduce operational effectiveness and efficiency through lack of teamwork and leadership and through reduced communication and coordination, and could cause misunderstandings and slips, lapses or mistakes.

## SUMMARY

18. This introduction attempts to highlight the multi-faceted and pervasive nature of Human Factors in civil aviation safety. Readers interested in more detailed information should consult the *Cabin Attendants' Safety Training Manual* (Doc 7192, Part E-1) and the *Human Factors Guidelines for Safety Audits Manual* (Doc 9806). To assist in understanding the complex interactions of Human Factors and the multi-disciplinary nature of its study, the SHEL framework is briefly described. Since human errors are cited frequently as being causal or contributory in aviation occurrences, an error classification system is presented. Since error is an integral part of all human endeavour, eliminating it completely is an unattainable objective. This highlights the need to manage and control errors as well as to mitigate their negative consequences through a systematic error management system (further details are provided in Chapter 4).

19. A growing number of Annexes contain Standards and Recommended Practices (SARPs) that require a demonstration of knowledge of human performance and limitations. Operational personnel must be able to demonstrate such knowledge under actual job conditions. Some SARPs identify specific skill requirements with respect to human performance. Others specify that particular documentation and programmes should be prepared and implemented in accordance with accepted Human Factors principles and knowledge. The list of Annexes to the Convention on International Civil Aviation that include Human Factors SARPs is found in Appendix A.

## ACKNOWLEDGEMENT

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# Chapter 1
# HUMAN FACTORS IN TEAMS

## TEAM PERFORMANCE

1.1 Within many operational settings team performance issues are becoming more predominant. Knowledge about teams has been evolving for decades, and significant progress toward understanding teams has been achieved. More is now known about team cohesion, team leadership, team communication, team decision-making, team competencies and teamwork than ever before.

1.2 Accordingly, individual, team, task and work characteristics influence team processes, which in turn influence team performance. Team performance requires more than individual performance; even qualified cabin crew may perform poorly as a team. When crew perform well together, they work in synergy. When in synergy, the performance of a team of people working together is higher than the sum of each individual's performance (Salas et al., 2000).

1.3 The cabin crew structure, with clearly defined roles and responsibilities for each crew member should contribute to increased synergy. Within the aircraft, the pilot-in-command is the flight crew commander. The senior cabin crew member reports to the pilot-in-command for any operational or commercial problem. The pilot-in-command informs the senior cabin crew member about operational or technical problems, who then informs the rest of the cabin crew. The senior cabin crew member interacts with a crew of up to ten or more.

1.4 To generate synergy among cabin crew, certain conditions need to be met:

- task allocation (i.e. Who does what?)
  - — the senior crew member allocates positions and roles in the cabin
  - — the safety training manual specifies to the cabin crew what has to be done, when, how and by whom
- authority allocation and leadership, since every team needs a leader
- a friendly and professional environment

1.5 The measurement of team performance has recently been receiving increased attention. Critical aspects of team performance are: which type of behaviours to measure and the level of analysis at which to measure, that is the measurement of team processes (e.g. communication and coordination) as well as team outcomes (e.g. correct decision) and the evaluation of individual or team competencies. Tools that can be used to measure team performance in terms of process include:

- observational scales
- critical incidents analysis
- expert ratings
- communication analysis

1.6 Team characteristics, such as cohesion, and team competencies also affect team performance. Team cohesion is affected by factors such as commitment to the task and the team's standards of acceptable performance. Cohesion has a stronger effect on teams in real-world settings and the commitment to the task appears to be the most important component of cohesiveness (Salas et al, 2000).

### Team leadership

1.7 To be an effective and efficient team requires a leader. The leader's role consists of:

- building the team
- explicitly stating expected results
- coordinating and monitoring activity
- managing workload and time
- preventing and addressing conflicts
- listening and implementing team member inputs
- making decisions

1.8 Leadership sometimes is associated with a recognized hierarchical position in an organization providing authority. The status of pilot-in-command and cabin supervisor is assigned by the airline. Leadership is also supported by characteristics such as personality, attitudes and values. Leadership is sometimes provided by someone who is not in a position of authority but because of particular competencies required by the situation (i.e. situational leadership).

1.9 A good leader has relevant technical knowledge, communicates effectively to diverse audiences in diverse circumstances, coordinates activities, manages the team, deals with conflict effectively and has superior listening skills. A leader also provides support to the team members by contributing to their development in delegating appropriate-level challenges in order for them to acquire autonomy. It is important that organizational policies support these leadership competencies and that selection tools assess them effectively and training programmes support their continued development.

## TEAM PERFORMANCE IN DIFFERENT AIRCRAFT TYPES

1.10 The requirements of some cabin crew members working on numerous aircraft of different types subject them to a mass of information necessary to apply many different procedures. When personnel are confronted with a severe abnormal situation, they confuse equipment type, location and utilization. Frequently during evacuations, cabin crew confuse the handle for inflating slides with the handle for slide separation from the cabin (Edwards & Edwards, 1990; Flight Safety Foundation, 2001; Hynes, 1998). These events have provided impetus for regulatory activity. The Joint Aviation Authorities' regulations (JAR-OPS 1.103) state that:

> Each cabin crew member does not operate on more than three airplane types except that, with the approval of the Authority, the cabin crew member may operate on four airplane types, provided that safety equipment and emergency procedures for at least two of the types are similar. Variants of airplane type are considered to be different if they are dissimilar in emergency exit operation; location and type of safety equipment; and emergency procedures.

1.11 The joint requirements for emergency and safety airborne equipment of the European Civil Aviation Conference (ECAC Doc 18) state that "for all types of aircraft having more than 19 seats, the number of required cabin crew is one for each unit of 50 passengers; and that the minimum number of cabin crew shall not be less than half the total number of Types A, I or II floor level exits" (see Table 3-2). They also state that "the number of aircraft types in which cabin crew are qualified at any particular time should be limited."

1.12 Recently, ICAO undertook a census of Contracting States to determine which regulations are in place to frame the operation of more than one aircraft type or variant by cabin crew. Half of the 69 States that responded to the census allow cabin crew to fly on multiple aircraft types but had not developed any specific regulatory requirements.

1.13 States also varied from two to no precise limits on the maximum number of aircraft types on which cabin crew can operate. There is a significant number of States that allow cabin crew to operate on more than one aircraft type and have no regulations governing conversion, differences or recurrent training for cabin crew on the operation the different types of aircraft. Consequently, States lack the capacity to regulate and oversee cross-crew qualification and mixed-fleet flying programmes involving cabin crew.

## CREW RESOURCE MANAGEMENT AND TEAM PERFORMANCE

1.14 To improve aviation safety and security, flight and cabin crew need to communicate, cooperate and work as a team. This is the role of crew resource management (CRM). ICAO has defined CRM as "the effective utilization of all available resources to achieve safety and efficiency." Furthermore, ICAO has adopted the concept of CRM as an error management training tool. The Federal Aviation Administration's (FAA's) definition is the following:

> CRM can be broadly defined as the utilization of all available human, informational, and equipment resources toward the goal of safe and efficient flight. CRM is an active process by crewmembers to identify significant threats, to communicate them, and to develop, communicate, and carry out a plan of actions to avoid or mitigate each threat. CRM also deals directly with the avoidance of human errors and the management and mitigation of those errors that occur.

1.15 Resources can refer to individual competencies, fellow crew members, aircraft systems, procedures, manuals, regulations, time, flight crew, passengers and other professionals. Resource management is the coordinated use of the available resources in attaining strategic and operational objectives.

1.16 CRM training is but one practical application of Human Factors. CRM is an on-going process that should occur throughout the flight and during pre- and post-flight activities. It involves planning, awareness of conditions and pre-flight communication, and includes all personnel performing those activities. Although CRM training can be approached in many different ways, there are some essential features. CRM training can be viewed as a family of instructional strategies that seek to improve error management and mitigation through teamwork in the aircraft by applying well-tested training tools (e.g. simulators, lectures, videos, role-playing) targeted at specific content (i.e. teamwork knowledge, skills and attitudes). CRM training focuses on the functioning of crew members as a team, not simply as a collection of technically competent individuals, and should provide opportunities for crew members to practise their skills together in the roles they normally perform in flight.

1.17 The CRM training programme teaches crew members how to use their interpersonal and leadership styles in ways that foster crew effectiveness and error management. The programme also teaches crew members that their behaviour during normal, routine circumstances has a powerful impact on how well the crew as a whole functions during high-workload and stressful situations. Similar situational experiences during training increases the probability that a crew will handle actual stressful situations with greater effectiveness and efficiency.

1.18 Pre-training factors, such as organizational, situational and trainee characteristics, can influence training effectiveness. A number of factors related to supervisory behaviours influence training effectiveness. The appropriate knowledge and commitment of senior management are the first step in the development of CRM training.

1.19 The literature suggests that incorporating known principles of practice and feedback into the design and delivery of training programmes can strengthen CRM training. CRM training that is consistent with theories of learning and provides relevant information about CRM behaviours, active practice and remedial feedback has a high probability of success (Salas et al, 2000).

1.20 Over the past several years, a wealth of knowledge has been generated with respect to teamwork, all of which is applicable to the design and delivery of CRM training. This knowledge can be used when analysing crew task requirements, observing crew, designing learning objectives, establishing feedback protocols, building scenarios for practice and evaluating crew performance.

1.21 Research indicates that culture can impact the effectiveness of CRM training. Cultural differences often impede the implementation in one State of off-the-shelf CRM programmes developed in other States. Four types of cultures have been found to influence CRM: the national culture of the crew member, professional culture, organizational culture and the organization's safety culture.

## CULTURAL DIVERSITY

1.22 Cultural differences have been recognized as an issue where Human Factors knowledge can be effectively applied. Helmreich and Merritt (1998) have provided the following description of culture :

> Culture fashions a complex framework of national, organizational and professional attitudes and values within which groups and individuals function. The power of culture often goes unrecognized since it represents 'the way we do things *here*' - the natural and unquestioned mode of viewing the world. However, the reality and strength of culture become salient when we work with a new group (whether in a new country, a new organization or a new profession) and interact with people who have well-established norms and values.

1.23 Cultural diversity among cabin crew and between cabin crew and passengers is an inevitable part of the operational and organizational environment. Awareness of cultural differences is necessary to minimize misunderstandings that may arise among crew members of differing cultural backgrounds and result in breakdowns in communication and coordination. Such issues can also be addressed with respect to the cultural diversity of passengers. Flight crew, especially those destined to operate in multinational crew, must be made aware of the significance of cultural diversity and the importance of understanding each individual's culture.

## SUMMARY

1.24 Team performance issues are becoming increasingly relevant in many operational settings. CRM is a standard method that is used in civil aviation to support team performance. CRM establishes a team approach to solving complex problems that can arise within the aircraft's work environment. The necessary leadership competencies are redefined within a team environment. Novel aspects for training are also present with the increase of culturally diverse crew as well as newly designed aircraft. Such newly emerging competencies may require a recasting of the frameworks underlying cabin crew training programmes.

1.25 Two issues of importance may also impact team performance: cultural diversity and aircraft type. Raised awareness among cabin crew of cultural diversity can enable and support strong team performance. With respect to differences in aircraft type, it may be necessary to determine the impact of working on diverse aircraft on cabin crew team performance levels.

# Chapter 2
# COMMUNICATION AND COORDINATION

## GENERAL

2.1 Central to team performance and CRM are competencies in communication. Communication takes place when information is transmitted from one or many senders to one or many receivers. Communication among flight crew, cabin crew and passengers plays a vital role in the performance of procedures concerned with aircraft operations under normal and abnormal operating conditions. The conditions and constraints of communication vary according to the people with whom the cabin crew must interface. Crew members communicate to exchange information, to build and reinforce common goals, action plans and expectations, to compare the understanding of a current situation, to monitor activity, to transmit the organizational culture (e.g. in creating a professional yet friendly work environment) and to avoid and address conflict situations. Joint training exercises on evacuations for flight and cabin crew have proved effective in resolving communication and coordination issues.

## CABIN AND FLIGHT CREW COMMUNICATION

2.2 Certain accident reports tragically demonstrate the criticality of timely and effective communication between the cabin and flight crew. The report on the Dryden accident[1] revealed, in a significant way, that such communication is not automatic and may be impossible due to differences in professional and organizational cultures. The Dryden investigation found that cabin crew did not communicate critical safety information (wet snow on the wing) for a number of reasons. Among reasons cited were professional respect, an assumption that the pilots were aware of all pertinent information and a reluctance to second-guess the pilots. Hesitation on the part of the cabin crew to transmit to the flight deck information that they considered critical for flight safety was noted. An examination of accident and incident reports has led Chute and Wiener (1994) to suggest five basic factors that influenced the differences between the two cultures and perpetuated the division and the problem as follows:

- *Historical background* — origins of the jobs and their influence on personal attributes and attitudes today
- *Physical separation* — lack of awareness of other’s duties, responsibilities and problems, each influences by lack of physical proximity
- *Psychological isolation*[2] — personality differences, misunderstanding of motivations, pilot skepticism and cabin crew ambivalence about chain of command
- *Regulatory factors* — sterile cockpit confusion and licensing issues
- *Organizational factors* — administrative segregation, training differences and schedules

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1. Moshansky, V.P. Commission of Inquiry into the Air Ontario Crash at Dryden, Ontario (Canada). Government of Canada, 1992.

2. It is important to note that security procedures designed to seal the flight deck, as currently proposed, can exacerbate the physical separation and psychological isolation among crew members.

2.3 The source of such hesitation may reside in the fact that the cabin crew may be "put in their place" by the pilot-in-command or fear that they are not respecting the "sterile cockpit". The notion of the sterile cockpit comes from the Federal Aviation Regulations FAR 121/542 as a result of controlled flight into terrain (CFIT) accidents. The FAR regulates that non-essential communication (i.e. not directly related to the actual conduct of the flight) to the cockpit is prohibited below 3 050 m (10 000 ft). This is associated with the fact that in many situations the flight crew are intensely preoccupied with the task of handling the aircraft and cannot focus on non-essential communication. Although the rule is useful in a wide range of circumstances since it protects the flight crew from potentially unsafe interruptions, it restricts cabin crew communication by discouraging them from reporting potentially vital information to the flight crew.

2.4 It is important that the extent of communication with the flight crew be regulated by the phase of flight and the completion of tasks. There are phases of flight where pilots are particularly busy and in those high workload phases, communicating with the cabin crew imposes additional demands on the flight crew. Consequently, communication should be kept to safety-critical information during the following phases:

- before and during take-off, because of workload and potential technical problems and counter-measures required to cope with them
- prior to and during landing
- ATC calls, because they require pilots' attention
- navigation or weather problems, since they require problem-solving and decision-making from the flight crew
- during emergencies

2.5 During an emergency evacuation, communication between the cabin crew and the flight crew consists of ensuring that the evacuation order has been given and transmitted, identifying usable exits and directing passengers so as to permit a rapid evacuation. During abnormal operations it is important that communication be clear so as to render evacuation easier and faster.

2.6 Aboard an aircraft, flight and cabin crew pursue the same objectives: flight safety, effectiveness and efficiency. However, the cabin and flight crew often have evolved within two distinct technical cultures. In most organizations, these two categories of personnel are managed by two separate departments. This organizational separation has resulted in discrepancies in training, manuals and procedures. It is important that the differences between the two professional cultures do not hinder optimal communication. Standardized training of certain procedures, such as emergency evacuations, is one way in which each group is exposed to the other's professional culture. Each must learn more about the other to ensure good communication during a flight.

2.7 Additionally, the cabin and the flight deck are physically very distinct and are separated by a locked door. This is especially true on wide-body aircraft, where this separation prevents contact between the flight crew and the cabin crew. The work environments are not only separate, they are also different. The flight deck is a relatively quiet and confined environment, and pilots remain seated. In contrast, the cabin is a spacious and relatively noisy environment. The cabin crew are in direct contact with passengers and have to move around the cabin. Therefore, the communication consideration for both flight and cabin crew is distinct.

## Crew briefings

2.8 Communication is also important for crew briefings and procedures to optimize coordination. Crew briefings are used to share common objectives, develop a common understanding of the situation and a common action. All crew need to know is who is doing what, when and how. Briefings are performed before every flight. Briefings should focus on the points that might diverge from routine and expectations. To be effective, briefings must be concise yet comprehensive.

2.9 ICAO has implemented Amendment No. 11 to the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS) (Doc 8168, Volume I, Part XIII, Chapter 3) with the recommendation that pre-flight crew briefings given by the pilot-in-command should involve all crew members. Where joint briefings are not held, the pilot-in-command should brief the senior cabin crew member who will then brief the other cabin crew members prior to each flight. Briefings should adhere to the following principles:

a) crew briefings should be short, including not more than ten items. If more than ten items are necessary, consideration should be given to splitting the briefing into sequential phases of the flight;

b) crew briefings should be simple and succinct yet sufficiently comprehensive to foster understanding of the plan of action among all crew members;

c) crew briefings should be interactive and where possible should use a question-and-answer format;

d) crew briefings should be scheduled so as not to interfere with, and to provide adequate time for, the performance of operational tasks; and

e) crew briefings should achieve a balance between effectiveness and continual repetition of recurring items.

2.10 Crew briefings that become recitations do not refresh prior knowledge and are ineffective. Pre-flight briefings should focus on crew coordination as well as aircraft operational issues and include but not be limited to:

a) any information necessary for the flight, including unserviceable equipment or abnormalities that may affect operational or passenger safety requirements;

b) essential communication, emergency and safety procedures; and

c) weather conditions.

2.11 Cabin crew briefings should prioritize all relevant conditions that exist for the departure and include but not be limited to:

a) assignment of take-off and landing positions;

b) review of emergency equipment;

c) special attention passengers;

d) silent review process (i.e. the self-review of individual actions in the event of emergencies);

e) review of applicable emergencies;

f) security or service-related topics that may impact passenger or crew safety; and

g) any additional information provided by the operator.

2.12 Briefings should also refresh all relevant procedures, especially if the aircraft is different from the one cabin crew typically work in, and crew should review how to evacuate, how to open the doors, the location of handles to inflate slides and the locations of fire extinguishers. Such briefings on procedures provide for a review of predefined action plans.

## Communications systems

2.13 Communication within an aircraft is typically completed through communications systems. Public address (PA) systems are typically used to convey messages to the passengers from the flight deck and/or the cabin. Intercom systems are used for communication between individual crew members. When such communications systems are out of order, communication between the cabin crew, the flight crew and the passengers is hampered. Consequently, the timeliness and reliability of the information to be transmitted can be negatively impacted. There are instances of failures of such systems documented in accident investigation reports.

## Safety briefing messages and signs

2.14 Other forms of communication used to transmit safety messages and coordinate activities in the case of an emergency are safety announcements and written or pictorial information to all passengers. Training prepares cabin crew to use additional comments and instructions to passengers in conducting evacuations. In particular, there is a requirement for briefings to passengers who are seated in an exit-row. Research studies demonstrate that passengers who receive exit-row briefings are more effective in evacuating the aircraft.

2.15 National regulations require all airlines to provide a safety briefing and demonstration to all passengers. Individual safety briefings should be given by cabin crew to special needs passengers. This includes passengers who may need the assistance of another person to move expeditiously to an exit in the event of an emergency.

2.16 The safety of passengers is enhanced if they know what to do in the event of an emergency. Laboratory studies have demonstrated that individuals perform better when they have received instructions about the use of emergency equipment (Flight Safety Foundation, 2001). There is also evidence from accident reports that survivors are frequently those who have prepared themselves for an emergency. This is a minority.

2.17 Surveys show that less than 10 per cent of passengers review the briefing card while on board (FSF, 2001). Results derived from responses to a questionnaire distributed to passengers who were obliged to evacuate a B747 after an accident involving fire demonstrate that information on the card contributes to mitigating the potential for injury. Of 165 passengers, 144 responded to a question concerning the briefing card. Of the 63 per cent who had not read the card, 56 per cent were injured in evacuation-related causes whereas of the 37 per cent who had read the card, only 17 per cent were injured due to evacuation-related causes (see Hynes, 1998; FSF, 1998; 2000).

2.18 There are several factors contributing to the minimal attention paid by passengers to the safety briefing. These include the fact that the risk level is so low that they do not believe that an accident can happen to them; frequent travellers assume they know everything and they believe that if an accident happens, the chances of survival are nil, so the safety briefings are considered superfluous. Consequently, there is a critical need for the industry to develop methods that encourage the passengers to pay attention to the safety briefings.

2.19 The oral briefings before and during the flight are usually given on the aircraft PA system. It is extremely important, in the event of an emergency, that the cabin crew communicate quickly and clearly to all passengers on board. The PA system provides the standard means of achieving this objective. In the event of failure of the PA system, an alternative method of communication is necessary. During the evacuation, megaphones may be used to direct passengers once they are outside the cabin. These should be stored near doors and within reach of the shortest crew member, from a seated position where possible. One accident report found that some of the emergency equipment, which included two megaphones, was stowed in overhead bins in the cabin and not near the cabin crew stations. Consequently, during the emergency evacuation the cabin crew found it impossible to reach this equipment as passengers moved towards the exit.

2.20 Safety briefings that are provided following boarding tend to be long, often monotonous and when passengers are inattentive. In fact, the anticipation of departure, the typical long waits to check in, the noise and the sustained attention towards airport messages are factors that contribute to unfocussed attention by passengers once aboard. For numerous passengers, once settled in, are more relaxed and less attentive. It may, therefore, be necessary to present the safety briefings when passengers are more attentive. Also, methods need to be implemented that support passengers remembering key safety messages and maintaining a positive behaviour in the event of an incident.

2.21 A recent report[3] has recommended a different sequencing and timing of safety information. A review of this report may be useful in enhancing the attention that passengers provide to safety briefings. It is also important during cabin crew training that appropriate techniques be taught so that the tone of voice and behaviour of personnel performing safety briefings are distinct from service-related messages.

2.22 The tone in which cabin crew address passengers has a direct impact on the speed of executing emergency evacuations. Communicating to passengers in a firm and direct manner is one good way of containing panic and inducing an organized evacuation.

2.23 It is also possible through videos to project sequences of cabin crew training with explanations on the safety impact associated with disregarding the briefings and the important safety role of cabin crew. Educating passengers on the consequences of inattention is important in obtaining passenger readiness.

### Accessibility and availability of safety information

2.24 Safety briefing cards are not helpful to blind passengers; therefore an appropriate method is necessary to ensure that safety information is conveyed to them orally. Special considerations also have to be made for deaf passengers who require information to be received visually. However, if they are seated at the back of the aircraft, they may have difficulty following the safety demonstration by the cabin crew. In addition, problems may arise during emergency situations when environmental conditions reduce visibility. For example, following a decompression, there is a sudden fogging of the atmosphere, fire gives rise to smoke, the failure of all electrical systems on impact could result in sudden darkness. In such circumstances, a deaf person's the ability to see and comprehend visual instructions is drastically reduced or nil.

2.25 The problems associated with oral briefings and safety briefing cards are first, how to present the information so that it is readily accessible, assimilable and usable in an emergency. The second problem is how to ensure that passengers listen to or see and comprehend the oral briefing or demonstration and read the safety briefing card.

2.26 Guidelines issued by the International Air Transport Association (IATA, 2001) stress that briefing cards should be designed to be understood by passengers who are totally unfamiliar with aircraft and safety equipment, and who may have a limited understanding of any of the languages used. Guidelines for the design of briefing cards include:

- pictures with a minimum number of descriptive words are more acceptable than pictures alone, words alone or pictures with a large number of descriptive words

- a realistic understandable picture of good quality is preferable to an abstract drawing

2.27 One operational example normally includes an oral briefing and information on the briefing card for passengers about the proper use of the emergency oxygen supply in the aircraft. A survey shows that less than 15 per cent of passengers fully understand the briefing concerning the use of supplementary oxygen. This is confirmed by evidence that passengers do not respond appropriately to the appearance of oxygen masks, i.e. they

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3. See Estegassy, R. and Koning, Y. Etude réglementaire sur les évacuations d'urgence: Synthèse finale et recommandations. Dedale Company, September, 1999.

do not know how to use them. Studies show that, when practicable, instructions provided at the time of decompression are more effective than the pre-take-off oral briefing and the safety briefing cards.

2.28 Signs provide both information and instructions about the use of hardware systems in the cabin. Signs indicate the location of exits and the maximum weight that an overhead bin is designed to contain. They also provide information on the location of emergency equipment and instructions for its use.

2.29 There are design recommendations for signs. These relate to the medium by which the information is presented, the visibility of the sign against the background, the characteristics of lettering and pictures, and the location of the sign (IATA, 2001). Signs should be visible either by means of colour contrast with the surroundings, by illuminating them or by outlining them with a clearly demarcated border. Details are provided concerning the minimum size of letters and pictures to use to ensure their visibility under various levels of illumination, and the clarity of different colours used for figure and ground segregation.

**SUMMARY**

2.30 Communication is a key tool in the exchange of timely information under normal and abnormal operating conditions. Communication takes place primarily between cabin and flight crew to conduct crew briefings and exchange status information. Cabin crew also need to communicate safety messages to passengers. Some of this information is communicated through signs, briefing cards and demonstrations. Some deficiencies are highlighted with respect to the Human Factors considerations to increase passenger attention to safety information through briefings and signs. Inattention to this has been associated with the increased risk of injury to passengers.

# Chapter 3
# ABNORMAL EVENTS AND CONDITIONS

### STANDARD OPERATING PROCEDURES (SOPs) UNDER ABNORMAL CONDITIONS

3.1 Standard operating procedures (SOPs) specify a sequence of tasks and actions to ensure that procedures can be carried out in a safe, efficient, logical and predictable manner. SOPs should clearly describe:

- what the task is
- when the task is conducted (time and sequence)
- by whom the task is conducted
- how the task is done (actions)
- what the sequence of actions consists of
- what type of feedback is provided as a result of the actions (e.g. verbal callout)

3.2 To ensure compatibility with specific operational environments and compliance of personnel, SOP design should take into consideration:

- the nature of the operator's environment and type of operation
- the operational philosophy, including crew coordination
- the training philosophy, including human performance training
- the operator's organizational culture, including the degree of flexibility to be built into the SOP design
- the level of expertise of different user groups, such as cabin crew and flight crew
- the compatibility between SOP and operational documentation
- procedural deviation during abnormal or unforseen situations

3.3 It is critical that flight operations personnel be involved in the development of SOPs. Furthermore, operators should establish a formal feedback process from flight operations personnel to ensure standardization, compliance and evaluation of reasons for noncompliance during the SOP implementation and use.

3.4 SOPs should be formulated so that they match the capabilities and limitations of human performance. Consideration should be given to the response tendencies within a given set of circumstances and the procedures developed from them. Policies should be formulated by reference to a shared knowledge base, developed through training, so that any particular policy may be understood as the most appropriate choice from a set of options. Observance of these guidelines will lead to a high level of conformity, but in the event of a violation, steps should be taken to determine whether the policies, procedures and processes are in need of revision.

3.5 A great deal of cabin crew behaviour follows pre-planned procedures which are learned during the completion of “drills” during training. Such drills are recorded in the form of lists of actions to be carried out in particular circumstances. All these lists will be included with the manuals supplied to crew members and carried on board the aircraft.

3.6 There are advantages associated with this highly structured procedural approach, particularly in reacting to emergencies. Optimal solutions to problems are best achieved in conditions removed from the stresses of danger. Formalized procedures can be developed after consideration by different subject matter experts contributing to a precise procedural approach.

3.7 Checklists are an integral part of SOPs. They depict sets of actions relevant to specific phases of operations that cabin crew must perform or verify to ensure flight safety. Checklists also provide a framework for verifying systems that guard against vulnerabilities in human performance. The cabin crew manual contains abnormal and emergency checklists to aid cabin crew in coping with incidents such as fires, sudden decompressions or various emergency landings. These checklists guard against vulnerabilities in human performance during high-workload situations by:

- ensuring a clear allocation of duties to be performed by each crew member
- acting as a guide for decision-making and problem-solving
- ensuring that critical actions are taken in a timely and sequential manner

Either the pilot-in-command or the cabin supervisor will provide the signal to initiate particular actions, according to the circumstances.

3.8 A concern may arise with respect to the effectiveness of carrying out emergency procedures either from memory or by reference to printed documents. Speed is the obvious advantage of memory, but the disadvantage is less reliability. A widely used compromise is to employ a number of reminders on the most urgent actions and a printed list.

3.9 While the advantages of practice are evident, a question arises concerning the circumstances in which the pre-planned procedures should be abandoned and alternative adaptive techniques employed to deal with abnormal conditions. In exercising personal judgement, crew members should remain aware of the relevant prescribed procedures and should have clear reasons for deciding to adopt alternative actions. One strength of highly trained human operators is that they are capable of producing prompt, innovative, flexible decision-making attuned to abnormal conditions.

## AIRCRAFT EXIT AND EVACUATION

3.10 The term evacuation is used in a generic sense and includes precautionary evacuations (PEVACs), abnormal deplanings and emergency exit situations. Evacuations are commonly referred to as “planned” or “unplanned”. In the case of a “planned” evacuation, cabin crew are advised that an evacuation is expected and some time is available to prepare the cabin and the passengers before the actual evacuation command is given. An “unplanned” evacuation is unexpected and there is no time between the decision to evacuate and the initiation of the evacuation.

3.11 Information obtained from reported events documenting the use of emergency exit systems and passenger evacuations is used by safety experts to evaluate the design and operational characteristics of evacuation procedures, systems and air crew training. Recent studies indicate that the FAA and the National Transportation Safety Board (NTSB) in the United States were not receiving or were not properly recording data on air carrier abnormal deplanings that occured every few days (FSF, 2001). Approximately 60 per cent of the events reported through other means were not contained in the FAA or NTSB databases. Given that evacuations associated with aviation accidents are rare events and that evacuation simulations fail to provide real data, it is important that information from all evacuations, including PEVACs, be collected and analysed.

3.12 Reports from the Aviation Safety Reporting System (ASRS) in the United States indicate that decisions to evacuate considered factors such as immediate interior and exterior hazards, condition of the aircraft, available exits, location of aircraft rescue and fire fighting (ARFF), distance to an airport gate, weather and terrain.

*Note.— Airlines do not generally have written policies on when to perform a PEVAC.*

3.13 Recently, the NTSB reported detailed information on evacuations that occurred between September 1997 and June 1999. This study included successful evacuations to determine which equipment and procedures worked well (FSF, 2001).

3.14 There were 46 evacuations recorded by the NTSB during the 16-month study. It was determined that on average, an evacuation occurred every 11 days. The events leading to an evacuation were varied, but the most frequent were: engine fire (actual or suspected) and cargo smoke or fire indications. Others included smoke in the cabin, cockpit and runway overshoot, and landing gear failure.

3.15 Thirty evacuations underwent detailed investigations wherein information was collected pertaining to the safety briefing card, the cabin diagram, flight and cabin crew manuals, training materials and syllabi, evacuation checklists and statements from all crew.

3.16 Questionnaires were sent to flight and cabin crew and passengers. The questionnaires sent to passengers consisted of questions regarding the preflight safety briefing, emergency exits, carry-on baggage, evacuation slides, passenger behaviour, seat belts, communication, injury, post-evacuation events and personal information.

3.17 Of 1 043 questionnaires mailed to passengers, 457 were returned representing 18 of the 30 evacuations receiving detailed investigations. Data from the evacuations were used to make 20 new safety recommendations to the FAA. Results from the study are summarized below.

3.18 The average age of passengers who responded to the questionnaire was 43 and 45 per cent of these were female. Of the recorded cases, 92 per cent of occupants were uninjured, 6 per cent sustained minor injuries and 2 per cent sustained serious injuries. In general, passengers were able to access aircraft exits without difficulty.

3.19 Emergency lighting systems functioned as intended in all of the evacuations investigated. In 43 of the 46 cases, floor-level exit doors were opened without difficulty. However, passengers had problems opening over-wing exits and stowing the hatch since the manner in which to do this was not self-evident nor clearly explained on the safety briefing cards.

3.20 Most passengers seated in exit rows do not read the safety information provided to assist them in understanding the tasks that they may need to perform in the event of an emergency evacuation, nor do they receive personal briefings from cabin crew in that regard.

3.21 Despite efforts and various techniques used over the years to increase passenger attention to safety briefings, a large percentage of passengers continues to ignore them. Although advisory circulars from the regulatory authority provide guidance in this respect, the safety briefing cards still do not clearly communicate safety to passengers. However, it was found that passengers do benefit from precautionary safety briefings just prior to emergency occurrences.

3.22 Globally, in 37 per cent of evacuations with evacuation slide deployments, there were problems with at least one slide. Such a high rate of failure increases the risk to safety of passengers and crew. In addition, evacuations involving slides are delayed when passengers sit at exits before boarding a slide, or when the crew does not direct them on how to get onto it. However, the majority of serious evacuation injuries occurs at the aeroplane door and at overwing exits without slides.

3.23 Limiting exit use during evacuations, as uncovered by the study, is not in accordance with the respective air carrier's existing evacuation procedures. At a minimum, all available floor level exits that are not blocked by a hazard should be used during an evacuation. Also, passengers' efforts to evacuate an aircraft with their carry-on baggage continue to pose a problem for cabin crew and are a serious risk to a successful evacuation. Techniques on how to handle passengers who do not follow directives from cabin crew need to be developed, implemented and evaluated.

**Communication during evacuations**

3.24 Communication between the flight crew, cabin crew and passengers plays a vital role in the performance of procedures associated with emergencies and evacuations. The initiation of an emergency evacuation serves as an example. There have been situations when cabin crew members have waited an excessively long time for the evacuation order from the flight deck. In one accident, cabin crew waited for a signal from the flight deck to initiate an evacuation, but communication was impossible as the flight deck had been separated from the cabin.

3.25 In a recent report by the Transportation Safety Board (TSB) of Canada, ineffective crew communication jeopardized the likelihood of a successful evacuation in several occurrences. Difficulties included the use of improper terminology leading to inaccurate assumptions by other crew members, delays by cabin crew in transmitting critical safety information to the flight deck and lack of confirmation of receipt of information — overall there was a total lack of communication. Ineffective crew communication often leads to ineffective crew coordination. As shown in occurrence data, poor crew communication results in unnecessary injuries or fatalities and unnecessary exposure to risk for passengers and crew.

3.26 The concern with standard terminology has no simple solution. In many situations, the flight crew are preoccupied with handling the aircraft and have no time for communicating with the cabin crew. Also, without mirrors or external video cameras, only a limited view of the aircraft exterior is available from the flight deck. The pilot-in-command is therefore dependent on others, such as air traffic controllers and cabin crew, to provide the relevant information in a timely fashion and therefore may not be the best judge of the most appropriate time to evacuate. Nevertheless, lessons have been learned to keep terminology and communication processes as simple as possible.

3.27 Standard terminology, consistent technical publications, checklists and signs are essential elements that contribute to keeping communication simple. This is of particular significance in operations where cabin crew are qualified on different aircraft types.

3.28 An example of the success obtained in using standard terminology is the incorporation of codes and required responses to SOPs. For example, these codes include key phrases announced over the PA by the flight crew as shown in Table 3-1.

3.29 Elements for successful implementation of communication policies, procedures and processes include:

a) the proactive prioritization of emergency communications as a critically important factor in crew performance and overall occurrence outcome. It must be adopted as an essential component of corporate safety priority and as part of the design profile for SOPs;

b) the simplicity of terminology adopted and applied through SOPs that can take on even greater significance with multi-cultural crew members with multiple fleet-type qualifications;

c) the procedures and processes must be incorporated into the very core of the training programme development and delivery; and

**Table 3-1. Codes used in SOPs**

| *Signal/Code* | *Meaning* |
|---|---|
| "Emergency Stations" (repeated twice) | Approximately two minutes to impact; conclude duties, en route to jumpseat |
| "Brace for impact" (repeated twice) | Approximately 30 seconds to impact; initiate brace shouted commands |
| "Evacuate" (repeated twice) | Commence evacuation |

d) to maintain their effectiveness, all communication procedures and processes must be subjected to continuous scrutiny by being included in all evacuation investigations.

3.30 Initiating an evacuation arises when there is no opportunity for premeditation of the emergency. There are instances of cabin crew initiating evacuations without informing the flight crew whose first knowledge of the event came from the illumination of the "door open" signal. All emergency evacuations are hazardous and injuries of various degrees of severity are incurred. Evacuations initiated by cabin crew are high-risk when engines are running and the aircraft is moving. It is important to empower cabin crew to initiate evacuations under defined conditions.

## Safety equipment

3.31 Regulations state that the means of opening emergency exits shall be rapid and obvious and shall not require exceptional effort. The types of exits most commonly encountered on passenger aircraft are Type A, Type I and Type III (see ). Type A doors, found on wide-body aircraft, are motor-driven in normal use and opened by turning or lifting handles that are located on the door. Type I doors are usually operated by rotating a handle mounted on the door 180 degrees in the direction indicated by a red arrow. The direction of rotation normally depends on which side of the aircraft the door is located. Type III exits, which are normally window hatches located over a wing, are more likely than other types to be opened by a passenger because cabin crew are stationed elsewhere.

3.32 The hatch, which weighs 22 kg (49 lb) (see Table 3-3), is designed to be removed by an individual in either a standing or sitting position by pulling a handle at the top of the exit. Using this handle with the bottom one allows the hatch to be lifted clear of the exit and pushed outside the aircraft. However, the weight of the hatch and the awkwardness of pushing it out of the aperture do not make this an easy task to accomplish effectively.

3.33 For Type III and Type IV exits, exit-seat passenger functions vary among air carriers and States. If the evacuation command is given, these passengers need to decide quickly on the following:

- whether the exit is safe to use
- how to open the exit hatch correctly
- how to follow instructions to stow the hatch without blocking the exit
- how to help stabilize overwing slides
- when to tell other passengers to move away from the aircraft

**Table 3-2. Dimensions of standard exit types**

| *Exit type* | *Minimum height* | *Minimum width* | *Maximum height of steps* |
|---|---|---|---|
| A | 1 830 mm (72 in) | 1 067 mm (42 in) | n/a |
| I | 1 220 mm (48 in) | 610 mm (24 in) | n/a |
| II | 1 118 mm (44 in) | 508 mm (20 in) | 254 mm (10 in) |
| III | 914 mm (36 in) | 508 mm (20 in) | 508 mm (20 in) |
| IV | 660 mm (26 in) | 483 mm (19 in) | 737 mm (29 in) |

3.34 Reports from cabin crew suggest that there are problems for passengers in operating the mechanisms that open the doors and windows, although regulations state that untrained persons should be capable of opening all exits from inside or outside. Problems are inevitable when there is no standardized method of opening these exits and when, in the same aircraft, some handles rotate clockwise and others counter-clockwise. This lack of standardization results in lost time and decreased effectiveness in an emergency situation.

3.35 Table 3-3 shows that different aircraft have exit doors with characteristics that vary over a wide range. This design variability is compounded by significant differences in the maximal forces applied by males and females. Twice the amount of rotational force could be applied by men than by women. The crew in the cabin is predominantly female; therefore, the amount of force required by them to operate exit doors should be considerably less than by men. Excessive force requiring the effort of several males is likely if the exit door malfunctions, for example, due to damage to the fuselage on impact or to poor-quality maintenance. Appendix B presents force limits for some of the tasks relevant to cabin crew.

3.36 Based on the performance of exit-seat passengers during actual and simulated evacuations, civil aviation authorities and air carriers are rethinking basic assumptions to ensure, as much as possible, that passengers in exit seats have the information to be able to operate the emergency exit and to help in an aircraft evacuation.

3.37 Some States currently require passengers seated next to Type III and Type IV exits to be briefed discreetly on the operation of these exits. Some States also have an exit-seat requirement restricting the categories of passengers who are seated in Type III and Type IV exit-seat rows to include disabled persons, the blind and deaf, the elderly or frail, children and infants (whether accompanied or not), obese passengers, deportees and prisoners in custody.

3.38 Recent research conducted in the United Kingdom concluded that providing exit-seat passengers with an additional detailed briefing about the operation of the Type III exit increased the probability that it would be operated quickly and correctly and in less time. Research also showed that participants who received additional exit briefings demonstrated increased awareness of their exit-operation responsibility and increased study of the exit diagrams.

3.39 IATA's Cabin Safety Working Group developed guidelines for seating passengers in rows adjacent to emergency exits. The guidelines emphasize the need for air carriers to have clear policies about exit-seat assignments by check-in agents, if a crew member believes that a passenger in an exit seat might impede an evacuation; the provision of passenger information sheets for emergency exit seats; and the need for advance briefings of cabin crew and passengers about aircraft configuration, specific restrictions, facilities and the seating of passengers who have special seating requirements.

3.40 Aviation regulatory authorities do not require training exit-seat passengers but do require that they be informed of their special role, have adequate information available to perform their exit-seat functions without assistance from the cabin crew and have no apparent inability or unwillingness to assist the crew during an emergency evacuation. Briefing methods for exit-seat passengers must fully consider the air carrier's overall cabin crew training, passenger safety communications and emergency policies and procedures.

## Evacuation slides

3.41 Prior to the 1950s, slides depended on the cooperation of able-bodied male passengers for successful implementation, two of whom were assigned to climb down the fabric chute after it was attached to the door sill and thrown out of the aircraft. During the 1950s, the inflatable slide of synthetic material was developed. It underwent a series of modifications, including a brake point at the bottom to prevent evacuees from coming into sudden and damaging contact with the ground and a fabric surface to reduce the possibility of losing inflation from punctures by sharp objects.

3.42 The design of slides should take into account the method of deployment and ensure that this is as error-resistant as possible. There are reports of difficulties in deploying slides; for example, they have failed to drop out of the aircraft and have had to be pushed out, using up precious time. On occasion, the slides have failed to inflate fully, thus reducing their effectiveness. Two safety studies analysing evacuations, one by the NTSB and the other by the TSB, discovered that evacuations requiring slides were hindered by problems related to deployment and/or angle of inclination in 7 of 19 occurrences in the former study and in 7 of 15 in the latter. This leads to a combined failure rate of 14/34 (41 per cent).

3.43 The exits from current aircraft are high above the ground. In a wide-body aircraft, the height of the exit can be 5 m (16 ft) from the ground and the top deck of a B747 about 8 m (26 ft). When an exit is more than 1.8 m (6 ft) above the ground, regulations require that it be equipped with "an approved means to assist occupants to reach the ground safely in an emergency." This takes the form of a self-supporting slide, which is deployed automatically in current aircraft when the exit opening mechanism is actuated and must be fully inflated within 10 s. In older aircraft, slides are deployed manually. In order to avoid automatic slide deployment during normal use of the door, armed and unarmed modes are available; the armed mode is selected by the crew as soon as the doors are closed and the aircraft is ready to taxi. The doors are unarmed by the crew when the aircraft again comes to rest.

3.44 While narrow-body aircraft have single slides, wide-body aircraft have double slides that can accommodate two people side-by-side. Slides are at the overwing exits of some aircraft, which reduces the risk of injury sustained by jumping from the wing to the ground. At the bottom of slides is a deceleration pad used to decelerate evacuating passengers into a standing position to facilitate rapid movement away from the aircraft.

3.45 In an accident, there is no assurance that the aircraft will come to rest in a normal attitude. Consequently, the slide may not assume the intended angle of about 37 degrees to horizontal. A significant discrepancy in either direction can lead to severe difficulties, including the case where the slide fails to reach the ground.

3.46 At angles of greater than 45 degrees, the speed of sliding increases sharply, and passengers are likely to balk at the steep appearance, adding to evacuation times. At around 28 degrees, the speed of sliding decreases and the passengers must push themselves down. High winds also cause problems in slide deployment and usability. The requirement for slides to be operational in winds of up to 40 km (25 mph) applies only to those installed since 1983.

3.47 It is operationally impractical to check the slide and its associated mechanisms on each flight due to time and associated cost. Replacing a deployed slide is something that requires time. It is therefore of major importance that the routine inspection, maintenance and repair of slides be carried out with the highest quality possible.

**Table 3-3. Selected examples of forces required to operate exit doors and slide handles and to move exit doors on different aircraft types**

| *Aircraft type* | *Exit door type* | *Force required to move handle to operate exit door or evacuation slide* | *Force required to move exit door* |
|---|---|---|---|
| B727-100/200 | Type I | door: 21 kg (46 lb)<br>slide: 9 kg (20 lb) | Normal: 23 kg (51 lb)<br>Emergency: 32 kg (71 lb) |
| | Type III | door: 7 kg (15 lb) | 21 kg (46 lb) |
| B737-200/300/400/500 | Type I | door: 21 kg (46 lb)<br>slide: 9 kg (20 lb) | Normal: 23 kg (51 lb)<br>Emergency: 32 kg (71 lb) |
| | Type III | n/a | 18 kg (40 lb) |
| B757-200 | Type I | door: 18.2 kg (40 lb)<br><br>door 3 left/right emergency: 120.5 kg (266 lb) | Normal:<br>door 1 left/right: 21.8 kg (48 lb)<br>door 2 left/right: 19 kg (42 lb)<br>door 4 left/right: 25 kg (55 lb)<br><br>Absence of assistance: door 1 left/right: 41 kg (90 lb)<br>door 2 left/right: 29.2 kg (64 lb)<br>door 4 left/right: 41 kg (90 lb) |
| | Type III | 14 kg (31 lb) | 22.7 kg (50 lb) |
| B767-200/300ER | Type I | door: 12 kg (26 lb) | 18 kg (40 lb) |
| | Type III | 14 kg (31 lb) | 27 kg (60 lb) |
| B747-100/200 | Type I | door: 10 kg (22 lb)<br>slide: 14 kg (31 lb)<br>747/400 door: 1 | n/a |
| DC-10-30 | All doors | 15.9 kg (35 lb) | Manual door 1 left/right: 84 kg (185 lb) for first 15 cm (6 in), then 36.4 kg (80 lb)<br><br>doors 2 and 4, 124 kg (273 lb) for first 15 cm (6 in), then 45.5 kg (100 lb)<br><br>door 3, 164 kg (362 lb) for first 15 cm (6 in), then 45.5 kg (100 lb) |
| A320 | Type I | door: 16 kg (35 lb)<br>slide: 14.2 kg (31 lb) | |
| | Type III | 3 kg (7 lb) | 14.7 kg (32 lb) |

3.48 Some injuries associated with slides are from falls over the sides, which has led to the suggestion that slide design incorporate high sides. Injured passengers in their turn are likely to disrupt the flow of evacuees from the aircraft or to cause injury to those who collide with them.

3.49 The advent of large-capacity aircraft has led to a requirement for type-specific training of cabin crew on this particular aircraft. There are several aspects of the aircraft (e.g. workout and rest areas) that induce passengers to spend more time away from their seats unbelted. This has led to a requirement for a qualitatively different approach to passenger management.

3.50 Large capacity aircraft has also led to a larger number of passengers, which contributes to the increased risk of panic at the slightest incident and to unintended consequences in an emergency exit situation. In an evacuation, the imposing height of the upper deck contributes to increased hesitation by passengers to embark on the escape slides.

3.51 In addition, passengers may not consider the two decks on large-capacity aircraft as independent, especially if they enter the aircraft by the lower deck. In numerous evacuations, passengers attempt to exit via their entry point rather than at other, more efficient exit locations (Air Accidents Investigations Branch, 1989; FSF, 2001). Consequently, passengers tend to use the stairs to exit from the lower deck, contributing to congestion at the lower front exits. As a result, a key role of cabin crew is to direct the passengers on the upper deck to a safe exit and prevent them from going to the lower deck. Thus, crowd control takes on a much larger dimension in the large-capacity aircraft and requires particular attention to training.

## Lighting

3.52 An emergency lighting system with an independent power supply is required in the cabin. This system must provide illumination for the cabin, emergency exit areas, emergency exit signs and exit locator signs.

3.53 Emergency lighting is an important factor since one of the many problems associated with a post-crash fire is the effect of smoke on visibility within the cabin. Smoke impedes evacuation and threatens survivability by obscuring exits, exit signs, aisles and obstructions. A particular problem is the stratification of smoke, which becomes more opaque as it approaches the ceiling. Illuminated exit signs, typically placed near the ceiling so that they are seen by all the occupants in the cabin, are likely to be obscured by smoke, while in the lower part of the cabin there is still some visibility. Also, the chemicals present in toxic smoke in the cabin, interact with the eyes so as to render passengers and crew virtually blind. Under such circumstances the net safety gains from any lighting system are minimal unless passengers' eyes are protected. Consequently, audible directional signals for exits should be evaluated for emergency use on aircraft.

3.54 As larger or brighter signs were shown to be relatively ineffective in compensating for high-smoke densities, a different solution is necessary. A study on the readability of self-illuminated signs in a smoke-obscured environment shows that substantial increases in the size of lettering results in moderate improvement in readability.

3.55 To counter the effects of smoke on the visibility of ceiling-mounted lights and illuminated exit signs, it is recommended that additional lighting be provided at or below armrest level. A study comparing ceiling-mounted and lower cabin-mounted lighting shows that evacuation times in laboratory conditions are reduced by up to one-fifth in a cabin filled with white smoke when emergency lighting and exit locator signs are mounted at or below the midpoint of the cabin, directly illuminating main and cross aisles. Compared with overhead lights and signs, the low-level lights also reduce disorientation.

3.56 In addition to lighting inside the cabin, lighting outside the cabin is important if evacuation takes place in the dark or in conditions of low visibility. Without adequate lighting, it may not be possible to see whether the evacuation slide is deployed and adequately inflated, or what the conditions are outside the aircraft. Lack of external lighting causes passengers evacuating over the wing to lose their sense of orientation and fall off the wing, sustaining injuries.

3.57 Not all Human Factors associated errors are due to shortcomings in design. During normal operation, accidents occur as a result of suboptimal maintenance. During emergencies, doors jam, slides fail to deploy, and safety equipment is missing. Human Factors is concerned with the management of the usability, reliability and error tolerance of equipment in addition to their design.

## CABIN FIRE

3.58 Fire, smoke and toxic gases present the greatest risk to a successful evacuation by restricting visibility, limiting communications, reducing the number of available exits, affecting passenger behaviour and decreasing a person's mental and physical capacities.

3.59 A safety study completed by the TSB on evacuations of large passenger aircraft documented that fire, smoke and toxic gases were identified as hazards in 11 of 21 evacuations and were present in three of four fatal occurrences. Thick black smoke severely restricted or totally obscured visibility in four cases where a fire occurred. As a result, passengers were unable to see the exits. Furthermore, cabin crew who were exposed to smoke and toxic gases experienced great difficulty in speaking and as a result, the emergency briefing was not clear to some passengers. The study also recorded a reduction in the number of available exits in nine occurrences.

3.60 In addition, an FAA study analysing the reports of 58 survivable or partially survivable aircraft accidents occurring between 1970 and 1993 demonstrated that smoke inhalation and burns were the primary causes of death in 95 per cent of the fatalities which occurred during evacuation.

3.61 Toxic gases released in a cabin fire significantly affect the respiratory systems of passengers and crew with rapid and sometimes fatal results. Passengers describe that one or two breaths of the dense atmosphere are sufficient to produce a burning acidic attack on their throats, causing immediate and severe breathing problems, weakness in their knees, debilitation and in some instances, collapse. Gases that are considered toxic and irritant when cabin fires occur include: acetaldehyde, acrolein[1] ($CH_2$ CH CHO), alipathic hydrocarbons, ammonia ($NH_3$), aromatic hydorcarbons (e.g. benzene, toluene), carbon monoxide (CO), hydrogen chloride (HCl), hydrogen cyanide (HCN), hydrogen fluoride (HF), nitrogen dioxide ($NO_2$) and sulphur dioxide ($SO_2$).

3.62 Smoke containing those chemicals contributes to choking and debilitating effects as well as to decreasing vision due to its extreme density and chemical effects on the eyes as mentioned in 3.53. To combat these effects, it was found that smokehoods can protect about 80 per cent of passengers, while burns from fire fatally injure the other 20 per cent of passengers.

3.63 Note that the rationale underlying the current approach to mitigating cabin fires is based on a fire-test programme carried out by the FAA concluding that the severe hazard from toxic emissions occurs as a result of flashover involving interior materials. The levels of toxic gases measured before flashover, or when flashover did not occur, were below levels estimated to prevent occupant survival. After flashover, occupant survival is virtually impossible, regardless of the level of toxic emission. However, numerous accident reports involving cabin fires have documented the finding that toxic and irritant gases which engulf the cabin, producing debilitating or incapacitating effects, are generated without flashover.

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1. Acrolein is one of the most irritant of the aldehydes produced by the combustion of cabin materials. It is an intense eye irritant and in low concentrations causes irritation of the upper respiratory tract. At higher concentrations, pulmonary oedema occurs, with death after only a few minutes exposure.

3.64 Numerous Human Factors studies demonstrate the importance of feedback for human operators within the system in order to assess the functioning of individual elements and methods and objectives of improvement. Feedback also allows more people to learn from the experience of those personnel who have survived an emergency evacuation. Feedback is critical since most cabin crew are unlikely to encounter an emergency evacuation.

3.65 If cabin crew members are unable to carry out their duties during an evacuation (due to injuries or other factors), they may suffer from intense feelings of guilt, which may result in post-traumatic stress disorder. Three factors are important in reducing the incidence and effects of post-traumatic stress disorders of cabin crew as follows:

a) the provision of help soon after the onset of stress;

b) the expectation that they will overcome their difficulties; and

c) that they will be able to resume their lives.

3.66 Potential victims of post-disaster stress are identified by their presence during an incident and should have immediate expert attention available to them. To help cabin crew learn to deal with stress, it is also necessary to incorporate pre-accident training so that if they experience an evacuation, they know what to expect and are capable of assessing their emotions and reactions as normal.

## PASSENGER MANAGEMENT[2]

### Cabin crew's role and responsibilities

3.67 Two aspects of the cabin crew's responsibilities are safety and service. The safety aspect is the subject of regulations. In addition to the staffing regulations, there are regulations covering the content of the safety training programmes for cabin crew. Regulations also prescribe certain activities to be carried out on every flight, such as oral briefings during specific times of the flight.

3.68 The primary function of cabin crew, as mandated by regulations, is to safeguard passengers by providing leadership in emergencies and by competently managing any potential hazards. The appropriate behaviour in such situations is authoritative and directive; however, this approach is not typically used. Most of the time there is no serious turbulence, no major decompression occurs, and there is no medical crisis. Fires on board are unusual and ditching and emergency landings are very rare events. Thus, cabin crew are infrequently called upon to exercise the competencies that comprise the statutory requirement for their presence on board.

3.69 There is a certain tension between the two aspects of the cabin crew's role, i.e. safety and service, that can impact effective performance. It is difficult, in an abnormal situation, for passengers to change their perceptions of the cabin crew from service provider to a figure of authority whose directives have weight and whose commands are to be promptly obeyed. Similar difficulties are experienced by the cabin crew in switching their interaction with passengers from one extreme to the other unless attention has been accorded to this issue during initial and/or recurrent training.

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2. The current digest will not attempt to address the emerging passenger-related security issues for cabin crew resulting from the events of 9/11/01.

3.70 Much thought and planning are required to balance cabin service with safety-related duties, especially during the critical phases of flight. Acknowledging passenger needs reduces passenger anxiety and increases passenger cooperation. An investigation of passenger complaints revealed that extreme cabin crew attitudes and confusion between their roles as service provider and safety overseer are the reason for a higher number of complaints. Incidents concerning service times on long-haul flights revealed two trends: those involving individual passengers occurred mostly during service down time; and group incidents occurred earlier in the flight.

3.71 Cabin crew need both to increase their vigilance, particularly during certain phases of flight, for warning signs of potential passenger misconduct and to intervene in a proactive way. When cabin crew are busy completing numerous tasks under pressure of time, they attend less to observable symptoms of passenger stress or distress.

## Disruptive passenger behaviour

3.72 The aviation system has developed an increasingly complex and sometimes inconsistent set of expectations aimed at the passenger. The airline passenger must conform to a restrictive set of behavioural norms when interacting with the aviation system. It is important that the passenger has a common view and acceptance of airline staff authority. In addition to coping with the logistical intricacies of modern-day air travel, passengers are expected to be knowledgeable about all passenger processing procedures; compliant with all safety and airline rules; attentive during safety briefings; and remain unaffected by fear of flying, nicotine withdrawal, excessive alcohol consumption, stress, fatigue or physical discomfort. In an emergency situation they are expected to evacuate an aircraft efficiently and effectively without any training, even after a long-haul flight crossing several time zones with cramped seating. Research indicates that most incidents of passenger misconduct occur during long-haul international flights (Dahlberg, 2001).

3.73 The ever-increasing presence of disruptive passengers on civil aircraft contributes to the heightened risk of safety and security in civil aviation, and as the number of passengers continues to increase, so does the number of disruptive passengers. A determined passenger who behaves in a violent or distressed manner can be as serious a threat as the presence of a fire in the aircraft.

### *Factors that contribute to disruptive passenger behaviour*

3.74 There are numerous factors that are hypothesized as contributing to the increased rate of disruptive passenger behaviour; they include:

- a more complete and systematic reporting of such incidents by airlines
- greater media coverage
- stress (e.g. fear of flying, airport environment)
- alcohol/chemical consumption (including medication)
- nicotine/oxygen deprivation
- lack of physical space
- psychological perception of lack of space
- increased load factors
- mental/physiological distress

- disconnection between the marketed images and the reality of commercial flight and societal factors
- changes in social behaviour associated with individuals accustomed to obtaining any information, products or services at the touch of a few mouse clicks
- the unrealistic expectations associated with the gratification from such instant service

3.75 Phobias may also increase the level of occurrences. Fear of flying affects a large proportion of air travellers and is frequently accompanied by other phobias. One study revealed that 55 per cent of passengers suffering from fear of flying are also afflicted with acrophobia (fear of heights), 46 per cent with claustrophobia (fear of confined spaces), and 4 per cent with agoraphobia (fear of open spaces). Another study revealed that 41 per cent of fearful flyers suffer severe anxiety, while 51 per cent suffer panic attacks (Dahlberg, 2001). It further showed that 65 per cent of fearful flyers use alcohol or drugs before and during flight to combat their phobia. It is important to note that the level of anxiety rises as an individual afflicted with fear of flying is faced with situations causing more anxiety (e.g. late arrivals/departures, precautionary landings). Recent disturbing incidents of passenger interference highlight the need for improved understanding of passenger behaviour linked to mental illness.

3.76 A recently completed survey (Guildhall University, 2001) of world airlines provides the rank order of causes for disruptive behaviours by the respondents: alcohol ingestion, passenger's demanding or intolerant personality, flight delays, stress of travel, smoking ban, cramped conditions in cabin, passenger denied carry-on luggage, passenger expectations too great, crew mismanagement of a problem and passengers denied upgrade. Passengers who are inebriated have been abusive to other passengers and to cabin crew, sometimes to the extent of physical violence.

3.77 Less common, but equally problematic, is the disruptive passenger as a consequence of substance abuse. Stimulants, depressants and drugs in their different ways have an effect on emotions and behaviour. Restless, agitated, abusive, violent and even psychotic behaviour may result from overdoses of stimulants while overdoses of depressive drugs may lead to loss of consciousness. Complex interactions with alcohol ingestion also occur.

*Measures for prevention of disruptive passenger behaviour*

3.78 The study of disruptive behaviour demonstrates that a series of small events can escalate to high levels, and early signs of potential disruptive behaviour may be observable (Dahlberg, 2001). The focus should be on prevention of disruptive behaviour by responding to early warning signs, rather than dealing exclusively with an escalated incident. Measures can be taken by airlines to maximize prevention. IATA recommends measures both internal and external to the organization. Measures internal to the organization include the following:

a) providing personnel with a clear policy on how to deal with disruptive behaviour, especially in its early stages;

b) ensuring a smooth operation: diffusing frustration that occurs with long waiting times, high passenger loads, lack of information, technical difficulties, etc.;

c) providing training for front-line personnel. This will include instructing ground staff and crew (cabin and flight deck) to learn how to recognize the early signs of potentially disruptive behaviour; ensuring that those who come in contact with a disruptive passenger have acquired the necessary dialogue skills and that they understand the importance of informing other operational areas of the situation to enable them to deal effectively with the passenger; and

d) maintaining accurate and updated reports and statistics of incidents that do occur so as to continually monitor the types of incidents and identify potential training needs.

3.79 External measures include communicating with passengers as follows:

a) prior to boarding, especially when groups are travelling together;

b) through dedicated information cards placed in seat pockets; and

c) through information on the flight ticket or e-receipt.

**Managing passenger conflict**

3.80 Today more airline incident reports refer to passenger behaviour. Conflicts arise during actual emergencies due to the intense stress caused by the situation. There are strategies that can be used by crew for managing passenger conflict during abnormal conditions as follows:

a) listen carefully and be particularly polite;

b) look for underlying causes, while continuing to maintain a professional attitude;

c) focus on what is right instead of who is right;

d) propose a solution that guarantees safety; and

e) close the conflict assertively if cabin safety is compromised.

3.81 With respect to more serious conflicts, e.g. fighting among passengers, rules to apply are:

a) guarantee the cabin safety;

b) involve other crew members; and

c) consult the pilot-in-command.

**Passenger behaviour in actual emergencies**

3.82 Aviation regulations require that for an aircraft to be certified, it must be demonstrated that it can be evacuated within 90 seconds. The main reason for this is to minimize the risk associated with potential fire or smoke to passengers. However, the 90-second evacuation requirement does not guarantee that all passengers will evacuate the cabin before it is penetrated by fire or smoke. As soon as smoke invades the cabin, the 90-second criterion is no longer valid because it does not address the effects of smoke and toxic gases upon passengers with breathing difficulty, loss of vision, induced panic and consequent disorderly behaviour associated with the evacuation. The requirement indicates that, given a closely ordered evacuation, the exit time can be minimized. It concerns how behaviour in a real critical evacuation can be positively influenced towards an optimum orderly exit.

3.83 Emergencies are unexpected and may be life-threatening. Surprise and induced fear lead to a very stressful situation for passengers and crew. Moderate levels of stress can improve performance and focus behaviour; however, under high levels of stress attitudes can deteriorate in a negative manner. Mental abilities, including perception, understanding and decision-making, can be impaired. There is also a chance that behaviours may become automatic and maladaptive, thus putting people at greater risk. Passengers have reported instances of competitive behaviours such as pushing, climbing seats and disputing. Faced with an unexpected, life-threatening situation, passengers typically react in one of two ways: overt panic (e.g. screaming, crying, hysteria, aggressiveness) or passive panic (e.g. inaction, freezing).

3.84 In many documented occurrences, passengers have stopped to retrieve carry-on baggage to take with them as they exit the aircraft, despite being specifically instructed not to by cabin crew. In addition, passengers often insist on exiting the aircraft via the same door they entered. There are also documented instances where passengers became fixated on a particular exit and made no attempt to look for a better exit route. In other cases, passengers climbed over seats to bypass others. The following example from the accident report at Manchester International Airport in 1985 illustrates this:

> From the statements of the survivors, it is evident that the effects of the fire on the left side of the aircraft rapidly instilled fear and alarm in many passengers. As the aircraft stopped, the aft cabin was suddenly filled with thick black smoke which induced panic amongst passengers in that area, with a consequent rapid forward movement down the aisle. Many passengers tumbled and collapsed in the aisle, forcing others to go over the seat-backs towards the centre cabin area, which was clear up until the time the right overwing exit was opened. A passenger from the front row of seats looked back as he waited to exit the aircraft, and was aware of a mass of people tangled together and struggling in the centre section, apparently incapable of moving forward, he stated "people were howling and screaming".

**Emergencies during the landing phase**

3.85 Ironically, emergencies leading to an evacuation occur more often during the landing phase than during any other phase of flight. This was the case in 9 of 21 (43 per cent) occurrences investigated in a TSB safety study completed in 1995. In addition, 73 of 166 (44 per cent) evacuation reports in the ICAO database (1993-2001) concerned an emergency which occurred during the landing phase of flight. In view of this, some States require a mandatory pre-landing safety briefing on flights of more than four hours to prepare passengers for the possibility of an emergency evacuation on landing.

3.86 There is evidence that suggests that passengers are least prepared to evacuate an aircraft in an emergency following a landing. During the landing phase, passengers are in a state of low response (e.g. they are fatigued, sleepy or bored after a long flight. In addition, passengers who are afraid of flying, feel relaxed as the flight nears completion; again, this results is a low response level. Consequently, their ability to perform life-saving actions or tasks during an evacuation are negatively affected.

3.87 A second explanation as to why passengers are less prepared to evacuate during the landing phase is they forget the information presented during the pre-take-off safety briefing. This is because the passenger safety briefing or demonstration is presented only once. The majority of evacuations are unplanned so there is no time to review safety information with the passengers. Therefore, those passengers who initially did not get the pre-take-off safety briefing will likely not get a second opportunity to be briefed.

3.88 If, during an evacuation, passengers are unable to perform certain tasks properly for the reasons stated in 3.86, or are unable to recall where their nearest or alternative emergency exit is located or how to operate it, as has been documented in accident reports, they may be unable to exit the aircraft successfully or may obstruct, prevent or delay the exit of other passengers.

**Special needs and elderly passenger considerations in emergencies**

3.89 Special needs passengers include expectant mothers and newborn babies, unaccompanied minors, children and infants, obese passengers, passengers with infectious diseases, incapacitated passengers and visually/hearing impaired passengers and the elderly.

3.90 Special needs passengers on board an aircraft require special individual briefings prior to taxiing. These briefings should cover safety and emergency procedures, cabin layout and any specialized equipment on board supplied by the airline. The briefing content should be standardized.

3.91 As stated in 3.89, special needs passengers include the elderly, who may need special attention in an emergency due to their frailty. Their lack of muscular strength and restricted movement leads to difficulties in operating the seat belt and in moving quickly to the exit in an emergency. In addition, the reduced atmospheric pressure in the cabin leads to mild hypoxia in elderly people, reduces cognitive performance and increases confusion. Some elderly individuals have difficulty recalling instructions because of loss of short-term memory and become easily confused and distracted in an emergency, requiring continual encouragement in order to make progress to the exit.

## EVACUATION RESEARCH

### Briefings in emergencies

3.92 Briefings under emergency conditions can prove to be invaluable. Reports gleaned from the United States ASRS documented flight crew reporting that PA system briefings concerning unusual sights, sounds, odours, vibrations and aircraft motions are valuable in maintaining calm and cooperative behaviour among passengers. Briefings to update passengers on actions being taken to evaluate and to resolve these unusual occurrences, including the possibility of an evacuation ordered by the Captain and clear instructions not to evacuate the aircraft unless directed by the flight or cabin crew, were noted in successful evacuations. Passenger-initiated evacuations were associated with an increased risk of injury in non-accident occurrences.

3.93 Emergency briefings should include the following information required by cabin crew from the flight deck in order to prepare for evacuation:

- the particular type of emergency situation
- whether a forced landing will be conducted on land or water
- how much time is remaining to touch down
- directions on who will make the announcement to passengers
- special instructions (e.g. which exits to use)

### Gender and age distribution of airline passengers

3.94 With respect to gender and age distribution of airline passengers, it was found that the number of females approached 50 per cent and that the number of passengers over age 60 was near 30 per cent. It is recommended that the required proportion for gender and age distribution of passengers in simulated evacuations follow these values rather than the current values established at 30 per cent for females and 5 per cent for passengers over age 60.

3.95 Gender was found to be associated with different injury rates, with the injury rate for female passengers being greater than that for males.

3.96 In spite of the difficulties of the elderly mentioned in 3.91, there appears to be no relationship between age and injury incurred; 34 per cent of passengers reporting injuries are over middle age, whereas 35 per cent are under middle age. However, elderly passengers have different perceptions of how their physical abilities affect their evacuation. Overall, they are not more likely to sustain an injury, but perceive their physical condition and age to hinder their evacuation.

## General

3.97 In a study on how motivation affects time in an evacuation using slides (McLean et al, 1996), it was found that the evacuation took less time when there was a financial reward associated with it. The study found that the following effects were produced by the competitive nature of passengers during the high-motivation trials: they became more aggressive, climbed over seats and outmanoeuvred others to get out quickly. However, significantly increased motivation impaired performance when the exit was small in size.

3.98 Related research in the United States identified over 500 evacuations that took place over a nine-year period (1988–1996) (Hynes, 1998). These were PEVACs associated with the deployment of emergency exit systems or where exit systems were not deployed, passengers and crew were required to conduct an unscheduled disembarkation at a different gate. It was estimated that 75 per cent of the evacuations were unnecessary.

3.99 Through the analyses of these evacuations, it was discovered that all of the cases involving a wide-body aircraft reported injuries. Also, almost every time an emergency exit system was deployed, injuries were reported as a result. In general, the injuries reported were as follows: 29 per cent minor, 42 per cent substantial and 29 per cent serious[3]. ASRS reports from the United States indicate that the risk of injury is greater when people exit an aircraft using slides or overwing hatches. In addition, a breakdown in radio communications among the flight crew, air traffic controllers and emergency response personnel was found to be a common factor leading to passenger injuries.

## SUMMARY

3.100 Abnormal events and conditions are considered one of the most stressful experiences that crew and passengers can face. Given the rarity of evacuations associated with aviation accidents, it is critical that information from all evacuations be collected, analysed and disseminated to the aviation community. Numerous aspects of aircraft exit and evacuation can help mitigate the risk of severe injuries. One such element is the SOPs, which are critical in the safe completion of evacuations. Communication is the critical link between the flight deck, cabin crew and passengers in the effective and efficient completion of SOPs associated with emergency conditions. One example of the criticality of communication is in the initiation of the evacuation. A primary objective of communication under abnormal conditions is to transfer vital information in a clear and concise fashion.

3.101 The safe undertaking and completion of an evacuation is critically dependent on the usability of safety equipment, such as exits and escape slides, found aboard aircraft. Another important factor is the competent management of passenger behaviours during abnormal conditions. The passengers on board aircraft will include special needs and elderly passengers, as well as disruptive passengers. The behaviour of these passenger groups needs to be managed with newly emerging competencies geared to support adaptive behaviours in all passengers during emergencies. The occurrence and severity of maladaptive behaviours are especially acute in the event of a cabin fire due to the fact that the presence of fire, smoke and toxic gases restricts visibility, limits communication, decreases mental and physical capacities and impacts passenger behaviours. Following an evacuation, it is important that timely and appropriate support be provided to all personnel and passengers. Support will minimally include training and counselling services, which help in reducing the frequency and severity of post-traumatic stress disorder.

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3. The cost of a serious aviation injury has been estimated to be $640 000 in the United States, while in the study the value of the average evacuation injury claim for which data were reported was $550 000 (see Hynes, 1998).

# Chapter 4
# ORGANIZATIONAL CONSIDERATIONS

## GENERAL

4.1 The digest so far has focussed on the aircraft, the cabin and its crew; however, they do not operate in isolation and are part of a much larger organizational structure. A brief description of Human Factors considerations within the larger organizational system is discussed in this chapter.

4.2 Drawing from the SHEL framework presented in paragraph 4 of the Introduction, the surrounding environment includes the organizational and management systems in which the individual must perform. Organizations may be viewed as dynamic entities; the managers and decision-makers run the organization, the various authority levels provide the structure, and the corporate culture provides the written as well as unwritten rules. Many Human Factors concepts can be applied to the organizational as well as to individual performance. Why are some organizations characterized as safe and others as unsafe?

4.3 Organizations have objectives that are usually related to production, for example, transporting passengers and goods and providing a regulatory climate that supports safe flight operations. Producing profit for shareholders is one of the principal goals of most commercial organizations. Therefore, safety must be present within the strategic and operational objectives of aviation organizations.

## ORGANIZATIONAL CULTURE

4.4 Organizational culture refers to the values, beliefs, assumptions, rituals, symbols and behaviours that define members of a group, especially in relation to other groups or organizations. Culture shapes behaviour and structures a person's perception of the world. It defines a collective mental model that distinguishes one human group from another. Norms are the most common, acceptable patterns of values, attitudes and behaviour for a group. Norms are reinforced by expressing disapproval of wrongdoers; how strongly members of a group sanction those who violate norms is an indication of the importance attached to those norms. It was believed that organizations were immune from the influences of culture and were exclusively influenced by the technologies they utilize or the tasks they pursue. Instead research has demonstrated that culture deeply influences the attitudes and behaviour of individuals within organizations, as stated by Helmreich and Merritt (1998): "It is the organizational culture which ultimately channels the effects of national and professional cultures toward standard practices, and it is the organization's culture which shapes members' attitudes toward safety and productivity."

4.5 Accident investigation reports invariably identify factors created by the organization which contribute to the emergence of an unsafe act. Frequently, human errors are committed in an environment that has overlooked or tacitly condoned such unsafe practices.

4.6 Cultures involve deeply rooted traits that are resistant to change. By identifying what comprises a safety culture and its characteristics, including its values, managers can optimize the existing corporate culture by setting examples. A safety culture within an organization can be defined as a set of beliefs, norms, attitudes, roles and practices concerned with minimizing the exposure of employees, managers, clients, and members of the general public to hazardous conditions. Such a culture, promoted among its members, supports a shared attitude of concern for the consequences of their actions, an attitude that covers material impacts as well as its effects on people. Helmreich and Merritt (1998) further characterize a safety culture as: "A safety culture is comprised of a group of individuals guided in their behaviour by their joint belief in the importance of safety, and their shared understanding that every member willingly upholds the group's norms and will support other members to that common end."

4.7 A safety culture is the product of commitment and engagement by senior management without which safety benefits would be short-lived. Promoting a safety culture requires large-scale investments. Effective airline managers know that although safety may be expensive, accidents can be even more expensive.

4.8 Attempts to enhance the safety of flight operations must address broader system issues as well as those at the individual and crew level. Below are some of the requirements for senior management to create and sustain a safety culture:

- Mutual trust and respect must be established with employees at all levels. This trust is dependent on a continuing demonstration of management's commitment to safety through its actions. This trust is fragile and may be easily undermined; it must be continuously sustained.
- A blame-free corporate philosophy, with clear accountabilities, must be developed and implemented. This requires managers to learn to accept errors as one outcome of human behaviour, distinct from accepting deliberate violations. Safety lessons should be learned from the daily occurrences of operational errors, and employees should feel free to openly share the details of their errors without fear of reprisals. Such elements are part of learning organizations.
- Pro-active programmes to identify error-inducing conditions should be implemented.
- As error-inducing conditions are identified, timely and appropriate action to minimize risks in the system must be taken and shared with all concerned.
- Training programmes that promote safe operating practices (e.g. CRM training and error management, specialized training for safety auditors).

4.9 Success in establishing a safety culture is highly dependent on the engagement and commitment of senior management. As risks to safety are identified, management should actively promote open communications and action by all employees without fear of reprisal on those who have identified the problem. The effects of a healthy, safety-oriented organizational culture can be observed in better defenses against potential safety threats in the system, and they can be felt economically in terms of greater efficiency and productivity.

## POLICY DEVELOPMENT AND IMPLEMENTATION

4.10 Within the life cycle of an aircraft there will be many changes in the deployment of resources. Equipment will be modified or replaced; SOPs will change; individual personnel will change and manning policies will be modified.

4.11 As an example, one airline established a communication philosophy stating that the timely, focussed and accurate communication among the entire air crew is an ongoing issue. It also specified that this philosophy must be exemplified, taught, practised and supported consistently in normal operations to ensure consistent application where it is most critical — in abnormal and emergency or crisis conditions. Such statements, when they accompany policies, can significantly support their implementation.

4.12 A hardware modification to equipment leads to the necessity for change in the procedures defining its use. This, in turn, leads to the necessity to modify manuals, checklists and signs, and to amend the initial and recurrent training programmes. Policies are necessary to ensure that these tasks are not overlooked, which otherwise could increase the risk to safety. The absence of these policies allows for the tacit acceptance of shortcuts, and as a result an emergency may not be handled effectively, resulting in injuries from the operational shortcomings. Alternatively, when mismatches (man and machine) come to the attention of operators, there is a tendency for them to create their own solutions by fixing the hardware or departing from the SOPs. The full impact of these unsystematic and unplanned deviances is not always evident, and unforseen consequences may be severe.

4.13 The fact that cabin crew exercise their passenger service-related duties during every flight creates an impression that their safety-related role is secondary to the marketing demands imposed by the airline management and the travelling public. This assumption, coupled with the fact that cabin crew rarely experience an emergency situation requiring the use of their safety-related training, affects their mental preparedness to handle sudden emergency situations.

4.14 Leadership and prioritizing actions to be taken are two of the main responsibilities of cabin crew in an emergency. These are responsibilities that could benefit from training in leadership and decision-making. Cabin crew training in these areas could emphasize their leadership role in aircraft cabins in an emergency. Relevant policies could be designed to reinforce their full responsibility for safety and emergency duties in the aircraft cabin and encourage them to undertake this responsibility to the maximum extent possible.

4.15 These policies, however, need to be integrated more fully into a complete organizational safety culture in all airlines. Such a culture would be supported by a more complete evaluation of safety-related competencies in the selection and training of cabin personnel should there be is an imbalance between their safety and service roles. This could impact the relevant policies for selection processes and continues through the employment of personnel within an organization. It is reinforced by the implicit and explicit messages conveyed to employees, in particular with respect to emergency evacuations where simulations are unrealistic and have no objective validation system. It is important that the airline industry apply a more focussed effort on promoting their safety message to passengers and all stakeholders throughout the industry.

## ERROR MANAGEMENT POLICIES AND PROCEDURES

4.16 Human performance is limited by the physiological limits on vision, perception, cognitive capacity, memory and attention. Physiological and environmental conditions such as fatigue and external stressors further limit performance. Excessive stress levels can impair performance and lead to errors through automatic reactions, regression to inappropriate habits and mental incapacitation. Error is inherent to human nature. This has led to a perspective that since human operators are error-prone, they should be removed from situations where error results in serious consequences, and human performance should be replaced by automated systems. Current automated systems are incapable of matching the required level of ingenuity, flexibility, knowledge and response possessed by humans. However, errors are the cost of human intelligence, knowledge and adaptability.

4.17 Helmreich and Merritt (1998) propose five precepts about error and its management as follows:

- In any complex system, human error is inevitable. In systems such as aviation where teams must interact with technology, errors will occur.

- There are limitations on human performance. All humans have limits imposed by cognitive capabilities such as the capacity of memory.

- When performance limits are exceeded, humans make more errors. When overloaded or under stress, decision-making ability is hampered.

- Safety is a universal value. In every culture, members value and strive to increase it. Safety is a continuum running from increased to decreased probability of accidents.

- High-risk organizations have a responsibility to develop and maintain a safety culture.

4.18 The management of human error requires at least two approaches. First, it is necessary to minimize the probability of errors by ensuring high levels of crew competencies; designing controls so that they match human characteristics (see Wagner et al. (1996) Human Factors Design Guide); providing proper checklists, procedures, manuals, SOPs, etc.; and reducing stressful conditions. In addition, appropriate and frequent training provides the conditions to develop appropriate habits, control over a stressful situation and efficient coping strategies and mechanisms. Training for efficient coping strategies includes the capacity to address the situation effectively; use acquired knowledge, skills and abilities; follow documented procedures; use all available resources; and observe teamwork practices. Training programmes aimed at increasing communication and coordination between crew members will reduce the number of errors.

4.19 The second method of managing human error is to minimize their consequences by cross-monitoring and crew coordination. Equipment design that makes errors reversible and equipment that monitors and supports human performance also contributes to limiting errors and their consequences. Experience, knowledge and proper training can assist crew in developing error recovery strategies and techniques.

4.20 Three strategies for error management are as follows:

- *Error reduction* strategies are intended to intervene directly at the source of the error by reducing or eliminating the contributing factors. Such strategies seek enhanced task reliability by eliminating any adverse conditions that increase the risk of error. Examples include the provision of improved and more frequent training; improved and streamlined SOPs, and improved teamwork.

- *Error capturing* assumes that the error has been made. The intent is to "capture" the error before adverse consequences arise. Error capturing is different from error reduction in that it does not directly impact to reduce or eliminate the error. Examples include post-task inspection, verification steps within a task and post-task tests.

- *Error tolerance* refers to the capacity in a system to accept an error without serious consequence.

4.21 It is important that deviations be used to adapt performance, i.e. by learning through error detection and recovery. An error management system includes elements of error prevention, error capturing and error tolerance. However, a complete error management system must go further by structuring the "learning from experience" through to the "consequences of error". Within an error management system, it is important to classify any performance deviation to determine the point in the input-output chain where things go wrong, or to seek patterns in the type of errors most commonly encountered. The classification of errors allows for the systematic description of their nature and the circumstances surrounding their occurrence and provides the foundation on which error management strategies are based.

4.22 A Human Factors audit can be used to improve the system design and management policies, procedures and processes. Auditing Human Factors Standards and Recommended Practices (SARPs) should form an integral part of all auditors' work as the implementation of all other SARPs is evaluated. The audit process can be regarded as the error detection and correction process and part of an organizational culture of risk management. The first phase comprises all the elements of the organization in which human components (people) are involved as operators (management and crew) or users (passengers). Errors, difficulties, delays, incidents and near-misses are documented, examined and archived. Interfaces are evaluated in relation to the well-being of personnel and the effectiveness and efficiency of system performance. Simulations can be used to investigate the impact of errors in various scenarios.

4.23 This descriptive information provides the basis of the second phase of the audit, the object of which is to devise modifications to improve the system. Such a modification might be located at any point within the system from the recruitment, selection and training of personnel to adjustments to hardware or policies, procedures and processes.

4.24 Feedback loops are one method of obtaining information on the behaviour of cabin crew, who perceive certain operational conditions relating to their duties and employ their skills to evoke the relevant responses. The impact of their actions contributes to succeeding inputs. The design of interfaces involving human performance is concerned with determining ways in which the incoming information may best be presented to ensure that it is promptly and accurately perceived, and that the consequent behavioural responses are facilitated in ways which minimize errors, delays or difficulties. A large part of the selection, training and retention process is devoted to selecting, building up, and maintaining the human aspect of information loops.

## SUMMARY

4.25 Information derived from accident investigations demonstrates that an emergency evacuation is a rare event at an organizational level and an extremely rare event at the individual level. However, it is during such rare circumstances that the safety role of cabin crew has a direct and important impact on the survival rate associated with an accident. A study by the European Transport Safety Council demonstrates that approximately 40 per cent of 1 500 people who perish in an aircraft accident die in "survivable" conditions. Slightly over half are victims of the effects of impact, whereas the remainder succumbs to events that occur post-impact, in particular, during the evacuation itself. Among the causes of increases in injuries and in the number of fatalities of passengers and crew is a subset in direct relation to the actions of the cabin crew — actions which are directly impacted by their training regime.

4.26 Common factors have emerged from incident investigations that are independent of the type of carrier, aircraft State of Registry and culture of the crew. These factors include the following:

- The performance of individuals in an emergency situation is directly linked to the capacity to put into practice automated behaviours based on trained abilities and competencies.
- Multi-type crew that work on different aircraft types can be the source of confusion in emergency situations.
- Situational stress significantly impacts the completion of tasks, alters decision-making and contributes to uncoordinated activities.
- The lethal effects of fire, smoke and toxic fumes, inappropriate and obstructive passenger behaviour and crowd control imposing real-world conditions for which crew are ill-trained.
- Communication among the crew, either between flight crew and cabin crew or among cabin crew themselves is often rendered difficult, if not impossible, due to stress, which leads to poor communication, or because sections of the cabin have been damaged.

4.27 In addition, numerous evacuation and survival hazards have been identified:

- Inappropriate and obstructive passenger behaviour — passengers retrieving their carry-on baggage and attempting to take it with them as they exit the aircraft.
- Access to a primary exit — impeded by carry-on luggage.
- Slides — rendered unusable by wind, partial deflation, escape slide/raft cover not retracting as designed and obstructing exit door.
- Crew coordination — lack of coordination between cabin crew and flight crew in an emergency situation — crew that have not participated in joint crew emergency procedures training.
- Communication — operable intercom system not used to relay critical safety information in a timely manner.
- Training — cabin crew emergency procedures training did not cover emergency equipment used on the aircraft.

- Manuals — discrepancy between emergency procedures described in the flight operations manual and the cabin crew manual.

- Post-evacuation survival — passengers inadequately clothed for survival in a harsh climate, lack of passenger control following evacuation.

4.28 Human Factors knowledge and principles can be effectively applied to addressing such issues relevant to cabin safety.

# Appendix A

## LIST OF ANNEXES TO THE CONVENTION ON INTERNATIONAL CIVIL AVIATION THAT INCLUDE HUMAN FACTORS STANDARDS AND RECOMMENDED PRACTICES

***Human Factors principles***. Principles which apply to aeronautical design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

***Human performance.*** Human capabilities and limitations that have an impact on the safety and efficiency of aeronautical operations.

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| Annex 1 – *Personnel Licensing* | Chapter 2 – Licences and Ratings for Pilots | 2.3.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>g) human performance relevant to the private pilot – aeroplane;<br><br>2.3.1.5 *Skill*<br>…<br>c) exercise good judgement and airmanship;<br><br>2.4.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>i) human performance relevant to the commercial pilot – aeroplane;<br><br>2.4.1.5 *Skill*<br>…<br>c) exercise good judgement and airmanship;<br><br>2.5.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>k) human performance relevant to the airline transport pilot – aeroplane; |

| Annex | Chapter | Paragraph number and text of the Standard or Recommended Practice |
|---|---|---|
| | | 2.5.1.5 *Skill*<br>…<br>e) procedures for crew incapacitation and crew coordination, including allocation of pilot tasks, crew cooperation and use of checklists.<br><br>2.5.1.5.1.1<br>…<br>c) exercise good judgement and airmanship;<br>…<br>f) understand and apply crew coordination and incapacitation procedures; and<br><br>g) communicate effectively with other flight crew members.<br><br>2.6.1.1 *Knowledge*<br>…<br>*Human performance*<br><br>f) human performance relevant to instrument flight in aeroplanes;<br><br>2.6.1.4 *Skill*<br>…<br>c) exercise good judgement and airmanship;<br><br>2.7.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>g) human performance relevant to the private pilot – helicopter;<br><br>2.7.1.5 *Skill*<br>…<br>c) exercise good judgement and airmanship;<br><br>2.8.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>i) human performance relevant to the commercial pilot – helicopter;<br><br>2.8.1.5 *Skill*<br>…<br>c) exercise good judgement and airmanship; |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| | | 2.9.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>k) human performance relevant to the airline transport pilot – helicopter;<br><br>2.9.1.5 *Skill*<br>…<br>d) procedures for crew incapacitation and crew coordination, including allocation of pilot tasks, crew cooperation and use of checklists.<br><br>2.9.1.5.1.1<br>…<br>c) exercise good judgement and airmanship;<br>...<br>f) understand and apply crew coordination and incapacitation procedures; and<br><br>g) communicate effectively with other flight crew members.<br><br>2.10.1.1 *Knowledge*<br>…<br>*Human performance*<br><br>f) human performance relevant to instrument flight in helicopters;<br><br>2.10.1.4 *Skill*<br>…<br>c) exercise good judgement and airmanship;<br><br>2.11.1.1 *Knowledge*<br>…<br>k) human performance relevant to flight instruction; and<br><br>2.12.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>g) human performance relevant to the glider pilot;<br><br>2.12.1.4 *Skill*<br>…<br>c) exercise good judgement and airmanship; |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| | | 2.13.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>h) human performance relevant to the free balloon pilot;<br><br>2.13.1.4 *Skill*<br>…<br>c) exercise good judgement and airmanship; |
| | Chapter 3 – Licences for Flight Crew Members other than Licences for Pilots | 3.2.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>e) human performance relevant to the flight navigator;<br><br>3.2.1.4 *Skill*<br>…<br>a) exercise good judgement and airmanship;<br>…<br>c) perform all duties as part of an integrated crew; and<br><br>d) communicate effectively with the other flight crew members.<br><br>3.3.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>o) human performance relevant to the flight engineer;<br><br>3.3.1.4 *Skill*<br>…<br>b) exercise good judgement and airmanship;<br>…<br>d) perform all the duties as part of an integrated crew with the successful outcome never in doubt; and<br><br>e) communicate effectively with the other flight crew members. |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| | Chapter 4 – Licences and Ratings for Personnel other than Flight Crew Members | 4.2.1.2 *Knowledge*<br>…<br>*Human performance and limitations*<br><br>e) human performance relevant to aircraft maintenance.<br><br>4.3.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>d) human performance relevant to air traffic control;<br><br>4.5.1.2 *Knowledge*<br>…<br>*Human performance*<br><br>i) human performance relevant to dispatch duties; |
| Annex 3 – *Meteorological Service for International Air Navigation* | Chapter 2 – General Provisions | 2.2.7 The meteorological information supplied to the users listed in 2.1.2 shall be consistent with Human Factors principles and shall be in forms which require a minimum of interpretation by users, as specified in the following chapters. |
| | Chapter 4 – Meteorological Observations and Reports | 4.1.9 **Recommendation.–** *At aerodromes with runways intended for Category I instrument approach and landing operations, automated equipment for measuring or assessing, as appropriate, and for monitoring and remote indicating of surface wind, runway visual range and cloud height should be installed to support approach and landing and take-off operations. These devices should be integrated automatic systems for acquisition, processing, dissemination and display in real time of the meteorological parameters affecting landing and take-off operations. The design of these systems should observe Human Factors principles. Provision should be made for the manual insertion of meteorological parameters in case of failure of the integrated automatic systems.* |
| Annex 4 – *Aeronautical Charts* | Chapter 2 – General Specifications | 2.1.1 Each type of chart shall provide information relevant to the function of the chart and its design shall observe Human Factors principles which facilitate its optimum use. |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| Annex 5 – *Units of Measurement to be used in Air and Ground Operations* | Chapter 3 – Standard Application of Units of Measurement | 3.3.1 The application of units of measurement for certain quantities used in international civil aviation air and ground operations shall be in accordance with Table 3-4. |
| | | 3.3.2 **Recommendation.–** *Means and provisions for design, procedures and training should be established for operations in environments involving the use of standard and non-SI alternatives of specific units of measurement, or the transition between environments using different units, with due consideration to human performance.* |
| Annex 6 – *Operation of Aircraft,* Part I – *International Commercial Air Transport – Aeroplanes* | Chapter 4 – Flight Operations | 4.2.5 Checklists<br><br>The checklists provided in accordance with 6.1.3 shall be used by flight crews prior to, during and after all phases of operations, and in emergency, to ensure compliance with the operating procedures contained in the aircraft operating manual and the aeroplane flight manual or other documents associated with the certificate of airworthiness and otherwise in the operations manual, are followed. The design and utilization of checklists shall observe Human Factors principles. |
| | Chapter 6 – Aeroplane Instruments, Equipment and Flight Documents | 6.1.3 The operator shall provide operations staff and flight crew with an aircraft operating manual, for each aircraft type operated, containing the normal, abnormal and emergency procedures relating to the operation of the aircraft. The manual shall include details of the aircraft systems and of the checklists to be used. The design of the manual shall observe Human Factors principles. |
| | Chapter 8 – Aeroplane Maintenance | 8.3.1 The operator shall provide, for the use and guidance of maintenance and operational personnel concerned, a maintenance programme, approved by the State of Registry, containing the information required by 11.3. The design and application of the operator's maintenance programme shall observe Human Factors principles. |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| | | 8.7.5.4 The maintenance organization shall ensure that all maintenance personnel receive initial and continuation training appropriate to their assigned tasks and responsibilities. The training programme established by the maintenance organization shall include training in knowledge and skills related to human performance, including coordination with other maintenance personnel and flight crew. |
| | Chapter 9 – Aeroplane Flight Crew | 9.3.1 … The training programme shall also include training in knowledge and skills related to human performance and in the transport of dangerous goods. … |
| | Chapter 10 – Flight Operations Officer/Flight Dispatcher | 10.2 **Recommendation.–** *A flight operations officer/flight dispatcher should not be assigned to duty unless that officer has:*<br>…<br>*d) demonstrated to the operator knowledge and skills related to human performance relevant to dispatch duties;*<br><br>10.3 **Recommendation.–** *A flight operations officer/flight dispatcher assigned to duty should maintain complete familiarization with all features of the operation which are pertinent to such duties, including knowledge and skills related to human performance.* |
| | Chapter 12 – Cabin Crew | **12.4 Training**<br><br>An operator shall establish and maintain a training programme, approved by the State of the Operator, to be completed by all persons before being assigned as a cabin crew member. Cabin crew shall complete a recurrent training programme annually. These training programmes shall ensure that each person is:<br>…<br>f) knowledgeable about human performance as related to passenger cabin safety duties including flight crew-cabin crew coordination. |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| Part III – *International Operations – Helicopters*, Section II – *International Commercial Air Transport* | Chapter 2 – Flight Operations | 2.2.5 Checklists<br><br>The checklists provided in accordance with 4.1.3 shall be used by flight crews prior to, during and after all phases of operations, and in emergency, to ensure compliance with the operating procedures contained in the aircraft operating manual, the flight manual or other documents associated with the certificate of airworthiness and otherwise in the operations manual. The design and utilization of checklists shall observe Human Factors principles. |
| | Chapter 6 – Helicopter Maintenance | 6.3.1 The operator shall provide, for the use and guidance of maintenance and operational personnel concerned, a maintenance programme, approved by the State of Registry, containing the information required by 9.3. The design and application of the operator's maintenance programme shall observe Human Factors principles. |
| | Chapter 7 – Helicopter Flight Crew | 7.3.1 … The training programme shall also include training in knowledge and skills related to human performance and in the transport of dangerous goods. … |
| | Chapter 8 – Flight Operations Officer/Flight Dispatcher | 8.2 **Recommendation.–** *A flight operations officer/flight dispatcher should not be assigned to duty unless that officer has:*<br>…<br>*c) satisfied the operator as to knowledge and skills related to human performance as they apply to dispatch duties; and*<br><br>*d) demonstrated to the operator the ability to perform the duties specified in 2.6.*<br><br>8.3 **Recommendation**.— *A flight operations officer/flight dispatcher assigned to duty should maintain complete familiarization with all features of the operations which are pertinent to such duties, including knowledge and skills related to human performance.* |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| | Chapter 10 – Cabin Crew | **10.3 Training**<br><br>An operator shall establish and maintain a training programme, approved by the State of the Operator, to be completed by all persons being assigned as a cabin crew member. Cabin crew shall complete a recurrent training programme annually. These training programmes shall ensure that each person is:<br>…<br>f) knowledgeable about human performance as related to passenger cabin safety duties and including flight crew-cabin crew coordination. |
| Annex 8 – *Airworthiness of Aircraft,* Part IIIA – *Large Aeroplanes* | Chapter 2 – Flight | 2.2.1.2 The performance scheduled for the aeroplane shall take into consideration human performance and in particular shall not require exceptional skill or alertness on the part of the flight crew. |
| | Chapter 4 – Design and Construction | **4.1 General**<br><br>Details of design and construction shall be such as to give reasonable assurance that all aeroplane parts will function effectively and reliably in the anticipated operating conditions. They shall be based upon practices that experience has proven to be satisfactory or that are substantiated by special tests or by other appropriate investigations or both. They shall observe Human Factors principles. |
| | Chapter 8 – Instruments and Equipment | **8.1 Required instruments and equipment**<br><br>The aeroplane shall be provided with approved instruments and equipment necessary for the safe operation of the aeroplane in the anticipated operating conditions. These shall include the instruments and equipment necessary to enable the crew to operate the aeroplane within its operating limitations.<br>…<br>*Note 2.– Instruments and equipment design shall observe Human Factors principles.* |
| Part IV – *Helicopters* | Chapter 2 – Flight | 2.2.1.2 The performance scheduled for the helicopter shall take into consideration human performance and in particular shall not require exceptional skill or alertness on the part of the pilot. |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| | Chapter 4 – Design and Construction | **4.1 General**<br><br>Details of design and construction shall be such as to give reasonable assurance that all helicopter parts will function effectively and reliably in the anticipated operating conditions. They shall be based upon practices that experience has proven to be satisfactory or that are substantiated by special tests or by other appropriate investigations or both. They shall observe Human Factors principles. |
| | Chapter 7 – Instruments and Equipment | **7.1 Required instruments and equipment**<br><br>The helicopter shall be provided with approved instruments and equipment necessary for the safe operation of the helicopter in the anticipated operating conditions. These shall include the instruments and equipment necessary to enable the crew to operate the helicopter within its operating limitations. Instruments and equipment design shall observe Human Factors principles. |
| Annex 10 – *Aeronautical Telecommunications*, Volume I – *Radio Navigation Aids* | Chapter 2 – General Provisions for Radio Navigation Aids | 2.10.1 **Recommendation.–** *Human Factors principles should be observed in the design and certification of radio navigation aids.* |
| Volume II – *Communication Procedures including those with PANS status* | Chapter 5 – Aeronautical Mobile Service – Voice Communications | 5.1.1.3 **Recommendation.–** *In all communications, the consequences of human performance which could affect the accurate reception and comprehension of messages should be taken into consideration.* |
| Volume IV – *Surveillance Radar and Collision Avoidance Systems* | Chapter 2 – General | **2.2 Human Factors Considerations**<br><br>**Recommendation.–** *Human Factors principles should be observed in the design and certification of surveillance radar and collision avoidance systems.* |
| Annex 11 – *Air Traffic Services* | Chapter 2 – General | 2.22.1.1 **Recommendation.–** *In communications between ATS units and aircraft in the event of an emergency, Human Factors principles should be observed.* |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| | Chapter 4 – Flight Information Service | 4.3.2.2 **Recommendation.–** *Whenever such broadcasts are provided:*<br>…<br>*d) the HF OFIS broadcast message should take into consideration human performance. The broadcast message should not exceed the length of time allocated for it by regional air navigation agreements, care being taken that the readability is not impaired by the speed of transmission;*<br><br>4.3.3.2 **Recommendation.–** *Whenever such broadcasts are provided:*<br>…<br>*e) the VHF OFIS broadcast message should take into consideration human performance. The broadcast message should, whenever practicable, not exceed five minutes, care being taken that the readability is not impaired by the speed of the transmission;*<br><br>4.3.4.8 **Recommendation.–** *The Voice-ATIS broadcast message should, whenever practicable, not exceed 30 seconds, care being taken that the readability of the ATIS message is not impaired by the speed of the transmission or by the identification signal of a navigation aid used for transmission of ATIS. The ATIS broadcast message should take into consideration human performance.* |
| Annex 14 – *Aerodromes*, Volume I – *Aerodrome Design and Operations* | Chapter 9 – Emergency and Other Services | **9.1 Aerodrome emergency planning**<br><br>*General*<br>…<br>9.1.6 The plan shall observe Human Factors principles to ensure optimum response by all existing agencies participating in emergency operations.<br><br>9.2.35 The rescue and fire fighting personnel training programme shall include training in human performance, including team coordination.<br><br>9.4.2 **Recommendation.–** *The design and application of the maintenance programme should observe Human Factors principles.* |

| *Annex* | *Chapter* | *Paragraph number and text of the Standard or Recommended Practice* |
|---|---|---|
| Annex 15 – *Aeronautical Information Services* | Chapter 3 – General | 3.6.8 Human Factors considerations<br><br>The organization of the Aeronautical Information Services as well as the design, contents, processing and distribution of aeronautical information shall take into consideration Human Factors principles which facilitate their optimum utilization. |
| Annex 16 – *Environmental Protection*, Volume I – *Aircraft Noise,* Part V – *Criteria for the Application of Noise Abatement Operating Procedures* | | **3. Recommendation.–**<br>…<br>e) human performance in the application of the operating procedures. |

# Appendix B
# HUMAN STRENGTH LIMITS

The contents of this appendix are extracted from the Federal Aviation Administration's (FAA's) *Human Factors Design Guide* (Wagner et al., 1996).

The designer and Human Factors specialist needs to know the limits and ranges of human strength to create designs that are within the capabilities of potential users. If demands on human strength are too high, inefficient and unsafe worker performance will result. If the designer underestimates strength, unnecessary design effort and expense may be incurred.

The forces delivered by the human body depend on the contractile strength of the muscles, and the mechanical advantages of the body lever system with the joints serving as fulcra and the long bones serving as levers.

Knowledge of some of the many factors that relate to muscular strength may aid design personnel in understanding human physical capabilities. In addition to the strength capabilities of various body members, other factors include: age, endurance, gender, body build, body position, handedness, exercise, diet and drugs, diurnal variation, and emotional and fatigue states. Gender and handedness are discussed below.

In general, females are about 35 to 85% as strong as males with varying differentials for various muscle groups. Gender differences favour a greater range in joint motion in females at all joints except the knee. The preferred hand and arm are approximately 10% stronger than the non-preferred hand and arm.

There are three basic categories of strength: 1) Static strength, also known as isometric strength, which is a steady force exerted while the limbs are in a stationary or static position, 2) Dynamic strength, which is a force exerted by limbs moving in a smooth manner over time, such as while lifting an object, and 3) explosive strength, which is the application of peak amounts of strength for short periods of time, usually periodically, such as in running or sprinting.

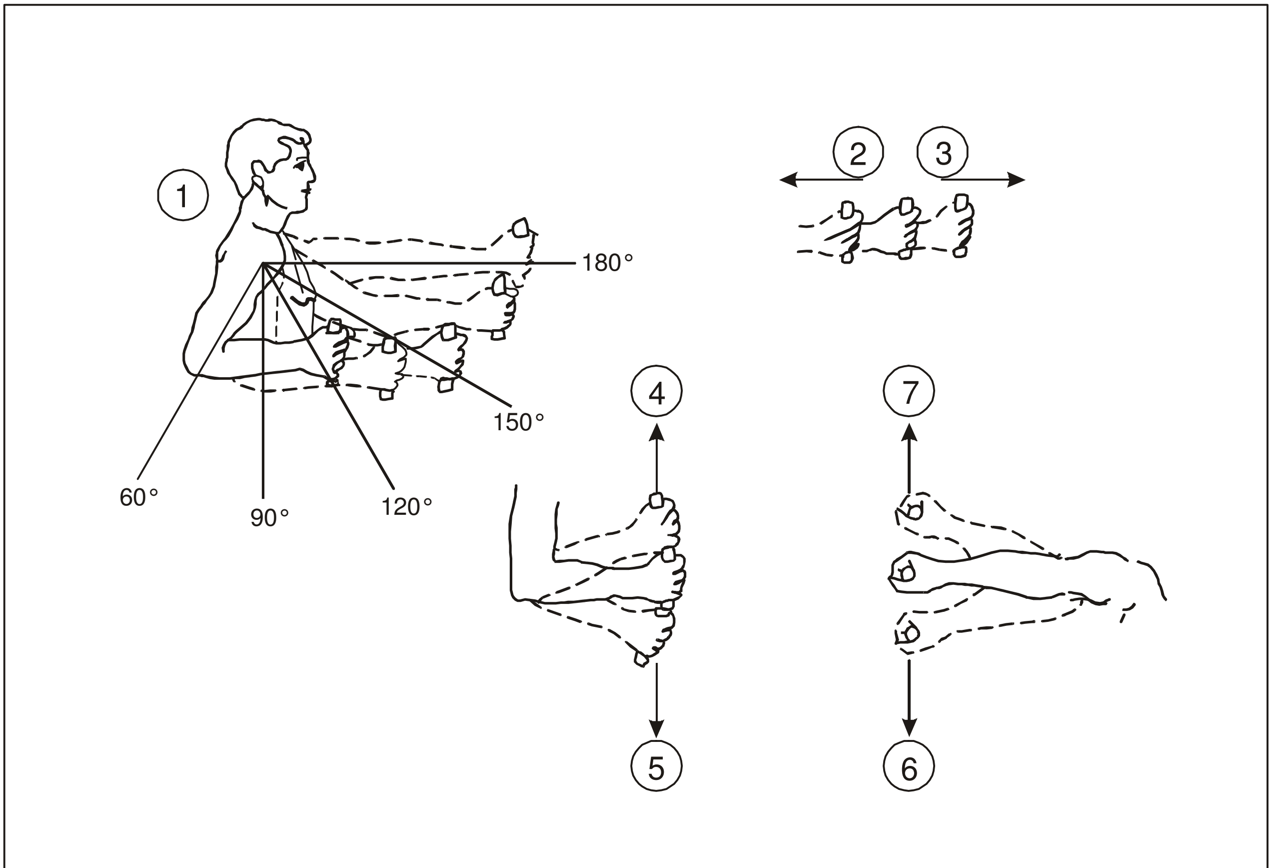
The maximum amount of force or resistance designed into a control should be determined by the greatest amount of force that can be exerted by the weakest person likely to operate the control. Control force limits, like most strength design limits, should be based on the 5$^{th}$ percentile (or, for critical tasks, the 1$^{st}$ percentile) of the female user population.

The figure below represents 80% of the maximum exertion forces for the 5$^{th}$ percentile male for the arm, hand and thumb. Research has produced little insight into the strength of women relative to men. The following strength relationships developed by the US Army Research Institute of Environmental Medicine should be used until better data becomes available:

1) For upper extremities, female strength is 56.5% of men.

2) For lower extremities, female strength is 64.2% of men.

3) For trunk extremities, female strength is 66.0% of men.




**Arm strength N (lb) Design criteria levels**

| 1 Degree elbow flexion | 2 Pull | | 3 Push | | 4 Up | | 5 Down | | 6 In | | 7 Out | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | R | L | R | L | R | L | R | L | R | L | R |
| 180° | 177.6 (40) | 184.8 (41.6) | 149.6 (33.6) | 177.6 (40) | 32 (7.2) | 49.6 (11.2) | 46.6 (10.4) | 60.8 (13.6) | 46.6 (10.4) | 71.2 (16) | 28.8 (6.4) | 49.6 (11.2) |
| 150° | 149.6 (33.6) | 199.2 (44.8) | 106.4 (24) | 149.6 (33.6) | 53.6 (12) | 64 (14.4) | 64 (14.4) | 71.2 (16) | 53.6 (12) | 71.2 (16) | 28.8 (6.4) | 53.6 (12) |
| 120° | 120.8 (27.2) | 149.6 (33.6) | 92.8 (20.8) | 128 (28.8) | 60.8 (13.6) | 85.6 (19.2) | 74.4 (16.8) | 92.8 (20.8) | 71.2 (16) | 78.4 (17.6) | 36 (8) | 53.6 (12) |
| 90° | 113.6 25.6) | 132 (29.6) | 78.4 (17.6) | 128 (28.8) | 60.8 (13.6) | 71.2 (16) | 74.4 (16.8) | 92.8 (20.8) | 56.8 (12.8) | 64 (14.4) | 36 (8.) | 56.8 (12.8) |
| 60° | 92.8 (20.8) | 85.6 (19.2) | 78.4 (17.6) | 120.8 (27.2) | 53.6 (12) | 71.2 (16) | 64 (14.4) | 71.2 (16) | 60.8 (13.6) | 71.2 (16) | 42,4 (9.6) | 60.8 (13.6) |

**Note.** L = Left
R = Right

Manual horizontal push and pull forces that are initially necessary to set an object in motion, or to sustain the motion over a period of time, should not exceed the values given in the figure below. For the second or third person applying horizontal forces, the value in the exhibit's first column should be doubled or tripled, respectively. For each additional person (beyond the third) another 75 percent of the force value in the first column should be added.

The figure shows maximum push and pull forces that a designer would be expected to use when appropriate body positions, support, and traction conditions are provided. Use of the maximum values shown in the figure is predicated upon a suitable surface for force exertion (vertical with rough surface approximately 400 mm (15.75 in) wide and between 0.51 - 1.27 m (1.673 - 4.167 ft) above the floor) to allow force application with the hands, shoulders, or back.

**Exhibit 14.5.3.1 Horizonal push and pull forces that can be exerted**

| Exertable horizonal force | Applied with | Condition (μ: coefficient of friction) |
|---|---|---|
| 110 N (24.7 lbf) push of [*sic*] pull | both hands or one shoulder or the back | with low traction $0.2 < \mu$ 0.3 |
| 200 N (45.0 lbf) push or pull | both hands or one shoulder or the back | with medium traction $\mu = 0.6$ |
| 240 N (54.0 lbf) push | one hand | if braced against a vertical wall 510-1520 mm (20.08-59.84 in) from and parallel to the push panel |
| 310 N (70.0 lbf) push or pull | both hands or one shoulder or the back | with high traction $\mu > 0.9$ |
| 490 N (110.2 lbf) push or pull | both hands or one shoulder or the back | if braced against a vertical wall 510-1780 mm (20.08-70.08 in) from and parallel to the panel<br>or<br>if anchoring the feet on a perfectly non-slip ground (like a footrest) |
| 730 N (164.1 lbf) push | the back | if braced against a vertical wall 580-1090 mm (22.83-42.91 in) from and parallel to the push panel<br>or<br>if the [*sic*] anchoring the feet on a perfectly non-slip ground (like a footrest) |

# Appendix C

# HUMAN FACTORS AUDIT ELEMENTS FOR CABIN CREW TRAINING

The information in this appendix is extracted from the *Human Factors Guidelines for Safety Audits Manual* (Doc 9806).

### 10.3.8 Training programmes cabin crew — Human performance knowledge

**Audit Authority:** Annex 6, Part I, 12.4 f) and Annex 6, Part III, Section II, 10.3 f), require that "An operator shall establish and maintain a training programme, approved by the State of the Operator, to be completed by all persons before being assigned as a cabin crew member. Cabin crew shall complete a recurrent training programme annually. These training programmes shall ensure that each person … *is … knowledgeable about human performance as related to passenger cabin safety duties including flight crew-cabin crew coordination."*

10.3.8.1 Training programmes for cabin crew, including the knowledge requirements for human performance, must be approved by the State. ICAO has provided some guidance for States in this respect in the *Training Manual* (Doc 7192), Part E-1, Chapter 7.

10.3.8.2 An important element of the training for cabin crew includes knowledge and skills in CRM. As for flight crews, effective CRM training requires three phases:

a) awareness of the common terminology relating to CRM;

b) practice and feedback, probably involving role playing in emergency situations; and

c) reinforcement which includes annual re-currency.

10.3.8.3 Given the practical nature of this training, the knowledge requirements are translated into operational settings. In essence, this application of knowledge involves skills development. In assessing States' implementation of these SARPs, safety auditors should find approved training programmes for each operator which include the following types of basic knowledge and skills development:

***Knowledge***

- importance of human performance in accident causation;
- common Human Factors terminology;
- concept of synergy (i.e. a combined effect that exceeds the sum of the individual effects);
- individual attitudes and behaviour versus team effectiveness;
- personal responsibility for maintaining fitness to fly;
- impact of organizational factors (e.g. corporate policies, procedures, practices and culture);

- management of available resources;
- setting priorities;
- importance of interpersonal relations to team building.

***Skills to be developed***

- communications and interpersonal skills, including:
  — barriers
  — cultural influence (See Chapter 4 of this Manual)
  — feedback
  — legitimate dissent
- situation awareness, including:
  — surrounding environment (e.g. phase of flight, aircraft serviceability, cabin state)
  — perceptions versus reality
  — fixation and distractions
  — monitoring (constant/regular)
  — incapacitation
- problem solving and decision making:
  — conflict management
  — review
- leadership and followership
- team building:
  — managerial and supervisory skills (i.e. planning, organizing, directing and controlling)
  — authority and assertiveness
  — roles (including command relationships with pilot-in-command)
  — professionalism
  — time/workload management

# Appendix D
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**— END —**

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