CONTENTS

SYNOPSIS

There is increasing recognition that methods which proactively monitor airline safety may be useful in preventing air safety occurrences. Proactive rather than reactive safety programs are particularly important, considering the high social and economic costs of airline accidents to the community. However, in the aviation industry, there are currently few formal proactive safety management systems in use, and none that reliably demonstrate the desirable goal of improving safety performance.

This paper outlines a new proactive safety method for the airline industry, called INDICATE (Identifying Needed Defences In the Civil Aviation Transport Environment). INDICATE is an airline self-management safety tool which encourages regular passenger transport operators to critically evaluate and continually improve the strength of their safety system. INDICATE also provides a formal communication channel for airline operators to regularly identify and report current weaknesses in aviation regulations, policies and standards to the Bureau of Air Safety Investigation (BASI), before they result in an accident. A major Australian regional airline is currently trialing INDICATE, so that an evaluation of its effectiveness and application to the wider aviation industry can be established. Preliminary results from this trial are presented.

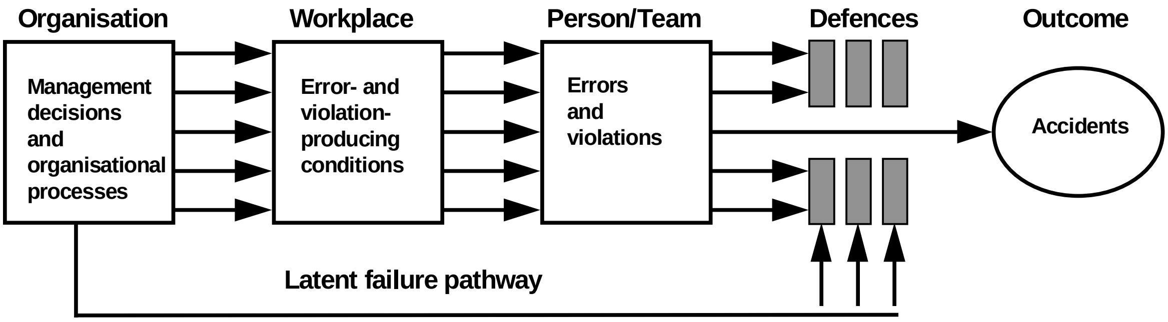
1. BACKGROUND

The challenge facing air safety investigators in recent years has been to develop better ways of investigating air safety occurrences. The systemic approach to accident investigation is now firmly established and has received wide acceptance as a result of some highly public aviation accidents. The crash of an Air Ontario Fokker F28 1000 at Canada's Dryden Airport resulted in a commission of inquiry that went beyond flight crew error as the principal cause and focused instead on systemic problems in the Canadian aviation system (Moshansky, 1992). In Australia, the accident involving a Piper Chieftain aircraft during a night circling approach in poor weather at Young, New South Wales, resulted in the loss of seven lives. The investigation of the accident highlighted significant deficiencies in the operation of the airline, and its interaction with the regulating authority (BASI, 1994).

Systemic investigations such as Dryden and Monarch have revealed that air safety occurrences frequently result from a set of similar safety deficiencies. Because aviation involves people, it is the failure of the human at some point in the system that dominates the accident statistics. The human failure may involve flight crew not following procedures, an incorrectly fitted component by a maintenance engineer, or the failure of management to provide adequate refresher training. What is unfortunate is that many of these human failures are recurrent and provide already well established (but not necessarily well learned) safety lessons.

There is increasing recognition that more effort should be directed at developing a reliable method that proactively monitors airline safety and minimises the potential risk of air safety occurrences. For airline managers, an effective proactive safety program represents very real financial benefits, considering the significant economic costs of an accident. However, in the aviation industry, there are currently few formal safety management programs designed to proactively prevent airline accidents. Much of the methodology behind these proactive safety programs is based on the work of Professor James Reason of the University of Manchester (Reason, 1990). Reason (1991) contends that modern aircraft accidents are generally the result of latent failures arising from the broad management functions of an organisation. Latent failures are decisions or actions originating within management that have damaging consequences but may lie dormant for a period of time. Reason (1995) has developed the following model (figure 1).

FIGURE 1
A model of organisational accident causation
(Adapted from Reason, 1995)



The model suggests that the direction of accident causality is from left to right. That is, accidents originate from latent failures arising from managerial decisions and organisational processes. These latent failures combine with local workplace factors, and errors or violations usually committed by operational personnel. If system defences are breached, the result may be an accident. The International Civil Aviation Organisation (ICAO) has recommended the use of this model to investigate the role of latent failures in aircraft accidents and incidents (ICAO Accident Investigation AIG Divisional Meeting, 1992).

While this model has been used successfully in the retrospective identification of accident-contributing factors, there are a number of proactive indicators that also base their methodology on the Reason model. These indicators periodically monitor those organisational latent failures that have appeared in catastrophic accidents, failures such as inadequate training, poor management communication, inadequate maintenance and poor equipment design. Shell International currently employ Tripod-DELTA (Hudson and others, 1994) in their drilling and exploration operations. Research at British Rail in the form of REVIEW (Reason, 1993) has focused on predicting or making latent failures more visible so that remedies can be implemented to improve safety. More recently Edkins and Pollock (1996) implemented REVIEW within an Australian public rail authority and found it a useful method for encouraging management and employees to become more involved in safety.

Within the aviation industry, British Airways has developed MESH (Managing Engineering Safety Health), which regularly assesses the current state of safety health along a number of situational and organisational dimensions (Reason, 1994). Organisational dimensions include organisational structure, training and selection, communication and people management. Situational dimensions include morale, fatigue or personnel safety features. The New Zealand Civil Aviation Authority has developed ASMS (Aviation Safety Monitoring System) a computerised management information system that not only stores information from air safety investigations but allows inspectors to carry out safety audits using typical organisational failure items similar to the organisational indicators employed by MESH. BASI has developed an analysis system which proactively identifies ineffective safety defences and recovery measures from aviation incident data.

Current proactive indicators such as MESH and REVIEW provide useful information to management on the safety health of their organisation. However, there are a number of reasons why such systems may not be directly transferable to the Australian airline industry. Some of these systems are limited by an over-reliance on subjective attitude measurement scales. Others require continual input from many employees from diverse areas to be considered valid. Furthermore, in the aviation industry these methods have only been applied in single operational areas rather than in the entire organisation.

Current proactive indicators are also limited by their exclusive focus on the identification of potential latent failures. Latent failures can be difficult to identify, may arise for complex reasons, and are often clearer after the event than before. Therefore, a model which focuses on proactively identifying and evaluating the adequacy of current system defences may be more useful (figure 2).

FIGURE 2
Proactive defence evaluation model

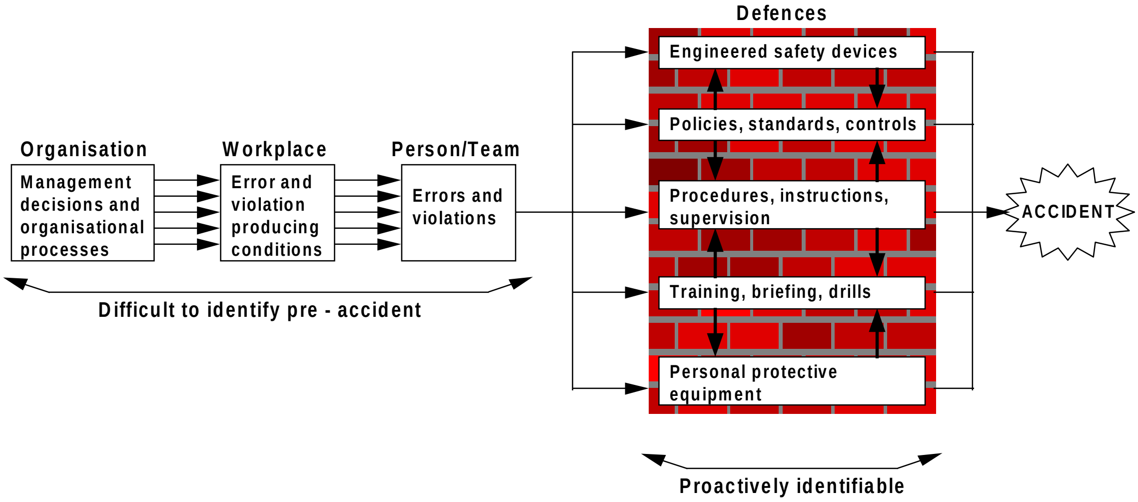


Figure 2 acknowledges that each of the organisation, workplace and person/team components of Reason's model are difficult to identify before an accident. This is because latent failures are usually unforeseeable, workplace factors are dynamic, and errors or violations are unpredictable. The model implies that the integrity of safety defences can be more accurately determined. This is because defences are tangible and thus measurable components in a system. It is much easier to evaluate the probable failure of a safety defence than to identify the potential existence of a latent failure.

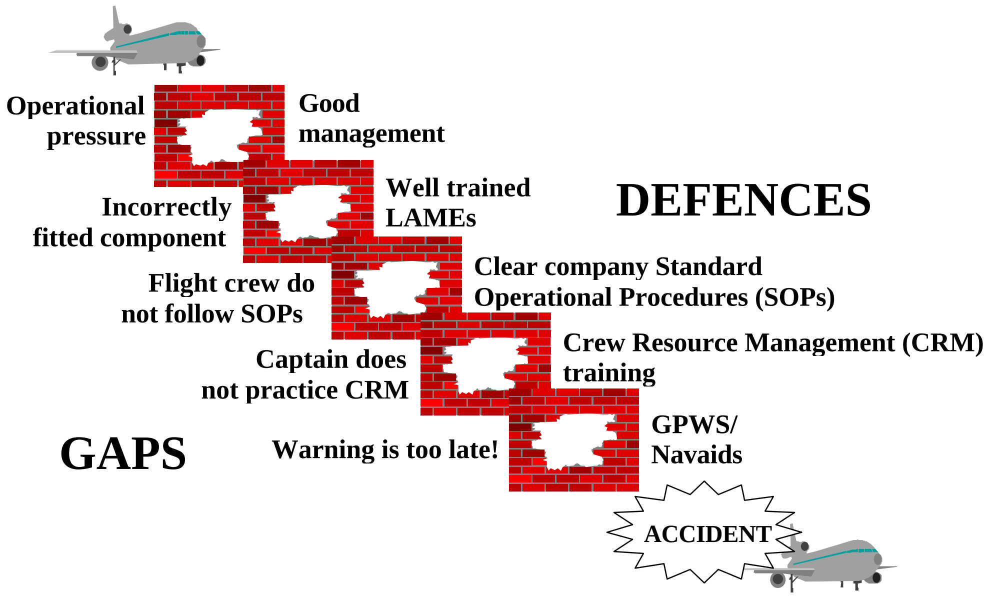
Defences are barriers or safeguards put in place to protect a system from both active and latent failures. For example, a Ground Proximity Warning System (GPWS) is a defence that offers the flight crew time to prevent a potential controlled flight into terrain (CFIT) accident. According to Maurino and others (1995), defences serve a number of essential functions, including:

- awareness and understanding (for example, Crew Resource Management (CRM) is a defence that is designed to highlight the value of crew communication);
- detection and warning (for example, a Traffic Collision Avoidance System (TCAS) provides flight crew with a timely warning regarding an impending collision);

- protection (for example, to avoid decompression sickness, modern aircraft are equipped with air-tight hulls and pressurisation systems;
- recovery and containment (for example, GPWS offers the flight crew time to recover from a potential CFIT accident); and
- escape and rescue (for example, in the event of an aircraft crash, an emergency locator transmitter (ELT) aids in the rescue of survivors).

Defences are important safeguards in maintaining an acceptable level of system safety. However, the breakdown of any one or a combination of defences can result in an accident. CFIT accidents have accounted for more fatalities than any other accident type. Figure 3 provides a hypothetical example of how failed safety defences can contribute to a CFIT accident.

FIGURE 3
Breakdown of safety defences in CFIT accidents



To avoid CFIT, figure 3 shows that an airline should have in place a number of defences. However, these defences can fail. Good management within an airline can break down due to operational pressure. Having well trained maintenance engineers does not ensure that aircraft components are always fitted correctly. The safe operation of commercial aircraft depends upon clearly written company SOPs and effective teamwork in the form of CRM, but not all pilots may follow standard procedures, or practice the principles of CRM. Finally, engineered safety devices like GPWS are designed to avoid CFIT, but an over-reliance may mean that the warning is too late.

It is important that an airline regularly identify what defences are currently in place to contain recognised safety hazards. In recognition of this need, and in line with its proactive policy, BASI is investing resources in developing for the airline industry an early warning safety system to enable both the Bureau and regular public transport operators to become more aware of safety issues prior to an accident.

2. PURPOSE

The purpose of this project was to trial a proactive safety program called INDICATE (Identifying Needed Defences In the Civil Aviation Transport Environment). INDICATE proactively identifies aviation safety deficiencies that have the greatest potential to compromise the safety of fare-paying passengers. A major Australian regional airline agreed to trial the project. Regional airlines are defined as airlines operating regular public transport aircraft with a capacity to carry up to and including 38 passengers. While the initial target group is regional airlines, it is expected that the results of this study will be made available to the wider aviation industry.

3. METHODOLOGY

The concepts upon which INDICATE is based are illustrated in figure 4.

FIGURE 4
INDICATE theory

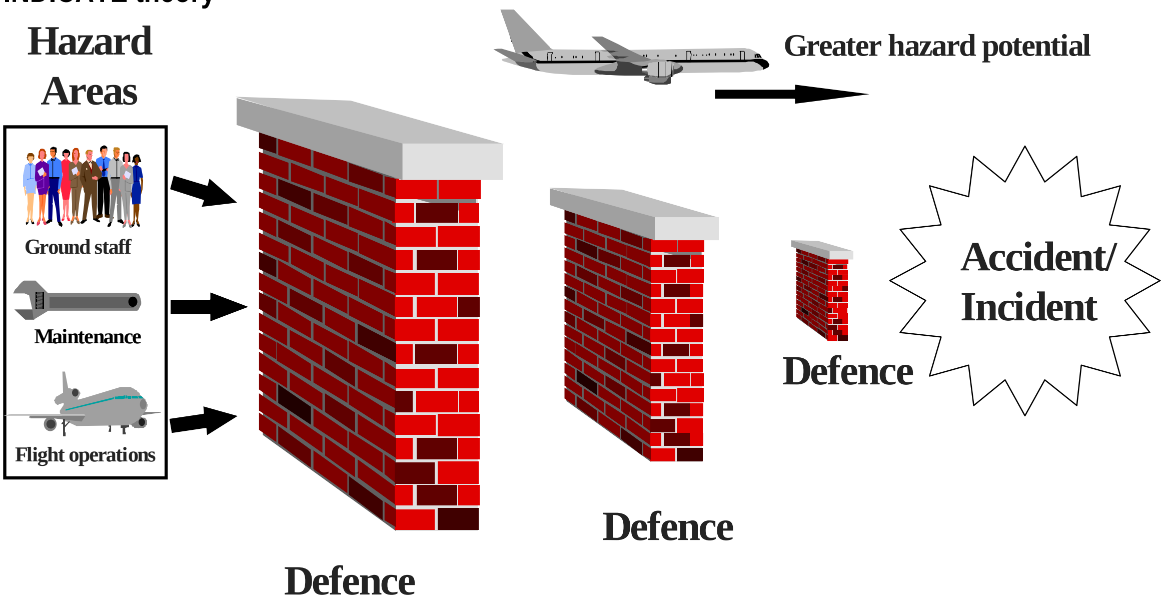


Figure 4 shows that in any given airline there are a number of operational areas: ground staff, maintenance and flight operations. Each operational area continuously has the potential to produce a number of safety hazards. To contain these hazards, the airline should have in place a number of defences. For example within the flight operations area, flight crew fatigue is a potential hazard that may compromise the safety of fare-paying passengers. Defences within the airline to contain this hazard may include Civil Aviation Orders (CAOs) specifying maximum flight crew time for a two-person crew, a company flight crew rostering system and a pilot union policy on crew work-rest schedules. Well designed defences provide protection against both individual and organisational error. However, because defences may lose their effectiveness over time, it is necessary to regularly monitor defence integrity so that the hazard potential is minimised. The hazard potential for crew fatigue, for example, may increase if the company flight-crew rostering system is not designed with human factors knowledge of proper work-rest schedules.

3.1 Implementing INDICATE

While current proactive safety indicators are designed to improve safety performance, there have been few attempts to formally evaluate their effectiveness. To encourage airlines to use and maintain a formal proactive safety program, INDICATE needs to demonstrate over time, significant improvements in safety performance for a given airline. The methodology behind the project was designed with this evaluation in mind (see appendix).

The airline which has agreed to trial INDICATE operates out of two major hubs. A total of 81 staff in hub 1 are receiving INDICATE for a six-month trial period. Seventy-one staff in hub 2 are not receiving INDICATE and can therefore be considered a control group. The purpose of a control group is to establish a baseline measure so that any improvements in safety can be established at the end of the trial.

INDICATE was established within hub 1 using the following four-step procedure.

Step 1. A sample of 81 airline staff were selected from three main operational areas:

- *Flight operations*: technical crew, cabin crew, check and training, airline operations staff.
- *Maintenance*: licensed and unlicensed aircraft maintenance engineers.
- *Ground operations*: baggage handlers, passenger catering staff, ground staff.

Airline staff were asked to participate in focus groups made up of six to eight people. Participants were asked to identify and rank in order of importance all the potential hazards that might threaten the safety of fare-paying passengers (for example, for flight crew an *engine power loss* is a hazard that might result in the loss of an aircraft, and its passengers.)

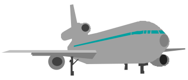
Step 2. For each identified hazard, airline staff were asked to determine the defences (procedures, controls or standards) currently in place to contain that hazard. (For crew fatigue, defences might include Civil Aviation Orders (CAOs) specifying maximum flying time for two-crew operations.) This step resulted in a list of defences in place within the airline to contain each hazard or combination of hazards.

Step 3. Airline staff were then asked to evaluate the effectiveness of those defences. For example, assuming that CRM were a defence, how widely was it accepted amongst technical and cabin crew? The outcome of this step was a list of deficient defences.

Step 4. Following the identification of deficient defences, airline staff were asked if additional controls or procedures were needed, or if further modifications to current defences were required.

4. INDICATE RESULTS

The safety hazards identified within each operational area are presented below.



Safety hazards: flight crew hub 1

- Instrument approaches
- High workload during passenger boarding
- Poor communication between operational areas
- Flight crew rushing flight checklists / inadequate checklists
- Mid-air collision
- Poor communication from Air Traffic Services
- Flight crew stress
- Cargo fire
- Poor airport ground lighting
- Failure to follow airline Standard Operational Procedures (SOPs)
- Information overload from Notices to Airmen (NOTAMs)
- In-flight turbulence
- Violent passengers
- Unsafe ground traffic movements
- Failure of passengers to listen to / follow instructions

Safety hazards: maintenance hub 1

- Poor communication between operational areas
- Lack of LAME re-training
- Poor communication within the maintenance department
- Time pressure
- Poor work continuity
- Lack of up to date maintenance manuals
- Poor cross-checking

Safety hazards: ground operations hub 1

- Poor passenger control on tarmac
- Lack of emergency training, equipment and procedures
- Insufficient airport tarmac lighting
- Damage to aircraft during towing
- Fuel spills / runway contamination
- Inclement weather

Flight crew

For flight crew, instrument approaches represent a significant safety problem, as some instrument approach procedures are impractical and encourage unconventional procedures. BASI recognises this and is liaising with the Civil Aviation Safety Authority to address the issue.

Tight turnaround times and a lack of ground staff assistance at some airports mean that flight crew are also under pressure during passenger boarding time. During this period of high workload, the potential to make mistakes is increased. The length and relevance of flight checklist items for specific phases of flight was also identified as a safety problem.

Maintenance

Poor communication, particularly between maintenance staff and flight crew, was identified as a potential threat to safety. This problem mainly refers to the inconsistent use of the maintenance release (MR). There is a strong perception amongst technical crew that if they write something on the MR it will automatically ground the aircraft. This problem partly stems from a lack of sufficient education from both flight and ground crew groups about the correct rules and regulations governing the use of the MR. As a result of this finding, airline senior management have arranged for a representative from both the flight crew and maintenance areas to conduct a series of educational workshops on the operational use of the MR.

Ground operations

Ground staff reported a lack of standardised response procedures for them to follow in the event of an emergency. In particular, they felt that they were ill equipped and poorly trained to respond to a ground emergency such as an engine fire during the start-up period. A related safety issue is inadequate communication between flight crew and ground staff during the engine-start period, as current hand signals are too restrictive to cover all the potential situations that could compromise passenger safety, and the use of communication headsets is not encouraged.

4.1 INDICATE output

Two types of hazards were identified through INDICATE: safety hazards that reflect deficiencies within the airline, and systemic safety problems that may compromise the safety of the broader aviation industry. The former are the responsibility of the airline to address internally, and the latter can be raised as safety deficiencies for BASI to investigate.

Table 1 presents an example from the ground operations area, and illustrates the type of information obtained for a particular hazard (lack of emergency training, equipment and procedures).

TABLE 1

INDICATE output

Airline Ground Staff

HAZARD: Lack of emergency training, equipment and procedures

DEFENCE	EFFECTIVE	REASON	RECOMMENDATIONS AIRLINE	RECOMMENDATIONS BASI
Clear Standard Operational Procedures (SOPs) for staff to follow in emergency situations.	No.	Current SOPs are non-standard, not published and not made available to all ground staff.	Recommended that the ground staff manager ensure that emergency SOPs and/or emergency checklists / contact numbers are accessible to all ground staff. Recommended that the ground staff manager conduct a general review of training requirements for ground staff in relation to emergency procedures and the conduct of aircraft evacuation drills.	
Regular staff-safety meetings.	No.	Not currently held in a consistent manner.	Recommended that the ground staff manager hold informal fortnightly safety meetings so staff have the opportunity to raise safety issues of concern to them.	
Communication aids.	No.	Communication headsets during engine starts are not currently used. Hand signals used by ground and flight crew are too restrictive and not universally applied.	Recommended that the ground staff manager and chief pilot request the standard use of headsets during the engine start period, to establish better flight and ground crew communication. Recommended that a review be conducted on the current use and adequacy of hand signals available for flight and ground crew communication.	
Emergency response training.	No.	Ground staff are unaware of the correct application of fire extinguishers.	Recommended that the ground staff manager contact the airport firefighting service and arrange a suitable training course.	
Emergency response equipment.	No.	Fire extinguishers are not easily accessible and are not fitted to all ground vehicles.	Recommended that the ground staff manager ensure that all ground vehicles are equipped with up to date fire extinguishers.	Recommended that BASI contact the Federal Airports Corporation over the optimal placement of fire extinguishers, so that they are closer to the aircraft loading bays.

As a result of the hazards that have been identified through the INDICATE program, BASI has raised the following safety deficiency advisory notices for further investigation:

- inadequate design of instrument approach procedures;
- non-reporting of unserviceabilities on the maintenance release;
- poor tarmac lighting at Adelaide Airport;
- poor taxiway lighting at Sydney Airport;
- security implications of carrying unaccompanied baggage;
- information overload from NOTAMs; and
- poor communication from ATS.

In addition, senior management within the airline have been informed about current staff safety concerns and provided with a list of suggested items requiring company safety action.

4.2 The maintenance of INDICATE

INDICATE has identified hazards that represent current aviation safety deficiencies. However, airlines operate within a dynamic environment and safety problems change over time. Therefore, staff are given the opportunity to identify additional hazards by using a Confidential Critical Incident Reporting form. This form can be used by staff to report any concerns they may have about safety within their work location. These may include witnessing or experiencing unsafe work practices, or identifying deficient safety equipment.

Once INDICATE has been established within an airline, it provides a framework for airline management to keep abreast of dynamic safety issues and to communicate this information to staff. To minimise the over-utilisation of valuable human resources, it is not a requirement for all staff to provide continual safety assessments. INDICATE only requires the managers within each operational area to meet as a group on a monthly basis. The purpose of this meeting is to manage and monitor the information obtained through INDICATE.

BASI is currently developing computer software that will enable the managers of each operational area to:

- monitor and amend a comprehensive list of hazards for each operational area;
- regularly evaluate the defences currently in place to contain those hazards;
- issue recommendations that specify where further defences are required;
- print out and send recommendations to airline senior management and/or to BASI; and
- monitor the current status of recommendations.

5. EVALUATING INDICATE

Before INDICATE was implemented in both hubs 1 and 2, a number of pre-intervention measures were taken so that INDICATE could be evaluated. Accidents are thankfully rare events and cannot be used as a statistically reliable index of safety performance. In recognition of this problem, two evaluation measures (safety climate and risk perception of aviation safety hazards) were used to determine whether INDICATE achieves an improvement in airline safety performance over the six-month trial period. These criteria were applied prior to the intervention, and will be re-administered at the end of the trial.

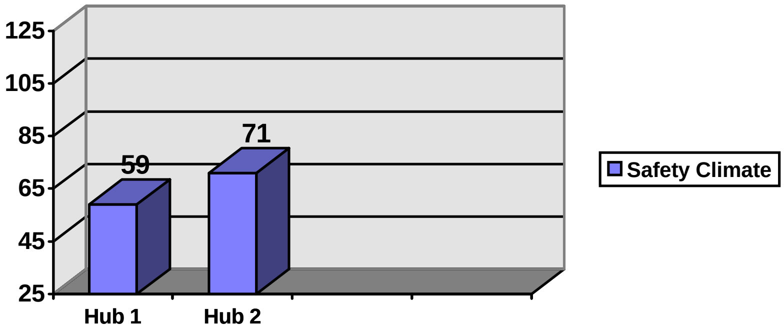
5.1 Safety climate

The procedures and rules governing safety within an organisation are a reflection of its safety climate, which is centred around employees' perceptions of the importance of safety and how it is maintained within the workplace. A good safety climate is characterised by employees sharing similar positive behaviours and attitudes about organisational safety. According to Cooper (1995) there are a number of core dimensions of safety climate, which include management commitment to safety, management action on safety matters, employee commitment to safety, risk levels perceived by employees, beliefs about accident causation, emergency procedures, safety training, and the effectiveness of safety communication within the organisation.

A questionnaire was constructed based on these dimensions. A reliability analysis of the questionnaire items indicated that the overall scale was equal to 0.9350.[1] Prior to INDICATE being implemented, the safety climate questionnaire was given to all staff across hubs 1 and 2. Mean scores for each hub are presented below (figure 5).

[1] Cronbach's alpha was used to determine the reliability. This is the average correlation (ranging in value from 0 to 1) of items within a test.

FIGURE 5
Pre-intervention airline safety climate scores



The safety climate questionnaire allows a score range from 25 to 125, with the lower the score, the better the safety climate. While the scores reveal that airline staff generally perceive that safety is managed in a positive manner, hub 1 shows a better safety climate score in comparison to hub 2.[2] If INDICATE is effective, it is expected that a redistribution of the questionnaire following the six-month trial period will reveal a further improvement in safety climate in hub 1, while there should be little change in mean scores for hub 2.

5.2. Risk perception of aviation safety hazards

The International Civil Aviation Organisation's (ICAO) Accident/Incident Reporting System (ADREP) was used to compile a list of the most commonly occurring aviation safety hazards in commuter/regional aircraft operations for 1979-1996. A final list of 22 safety hazards is presented below in figure 6. These hazards represent the most common contributing factors in terms of commuter/regional aircraft losses and passenger fatalities.

This list of aviation safety hazards was presented to participants. Participants were asked to rate each of the hazards according to its potential to affect the safety of fare-paying passengers carried by their airline. Each hazard was rated according to its *hazardousness* (the potential for the hazard to result in damage, injury or death), and the *likelihood* of it occurring within the airline environment. Mean scores were obtained for each rated hazard.

[2] An independent samples t-test revealed that this difference was statistically significant, $\underline{t}$ (1) = -4.63, p<0.001.

FIGURE 6

Common worldwide aviation safety hazards for commuter/regional aircraft 1979-1996

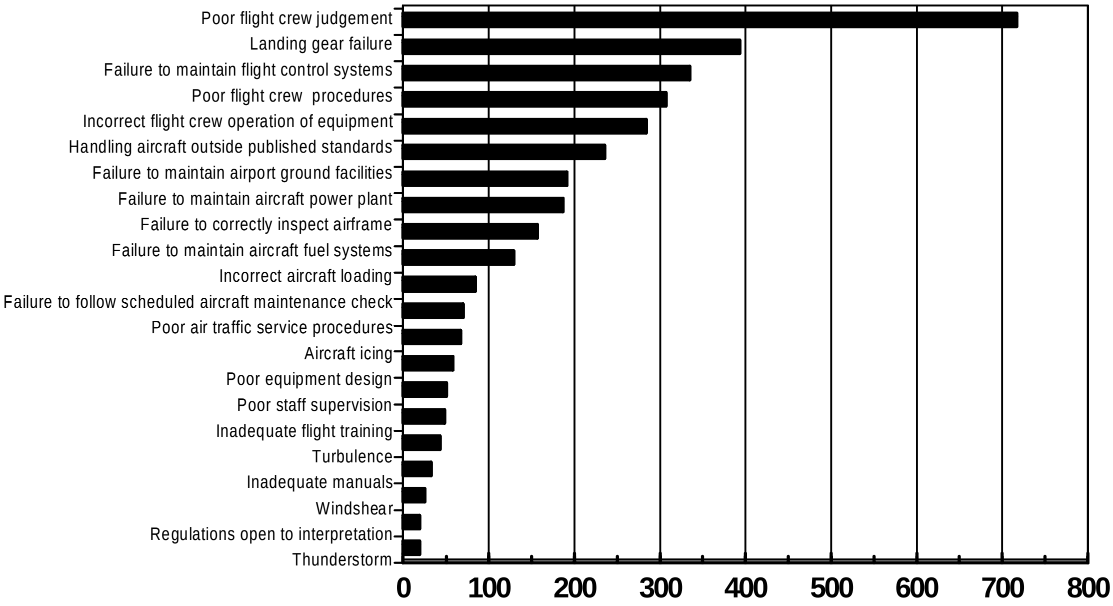
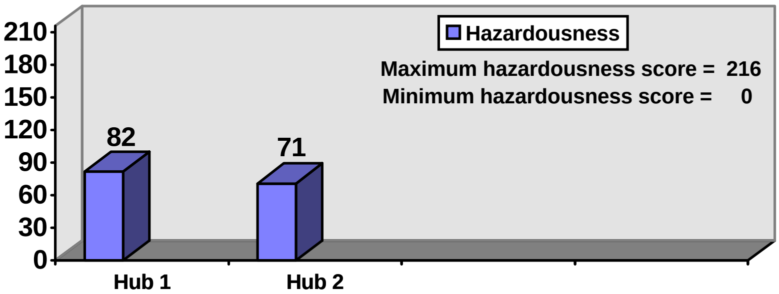


Figure 6 indicates that flight crew judgement is the most hazardous item according to accident statistics, however, airline staff in the present study rated those actions outside their control as more hazardous. For example, maintenance actions (failure to maintain flight control systems (M = 6.16), failure to maintain aircraft power plant (M = 6.12)), weather-related events (windshear (M = 6.07)), and organisational factors (inadequate flight training (M = 5.98)) were perceived as most hazardous. The same was true for the likelihood rating with weather-related factors (turbulence (M = 4.43), icing (M = 4.23), and thunderstorms (M = 3.77)) selected as the most likely hazards.

These results suggest that airline staff underestimate their own contribution to accidents and overestimate the contribution of others. This phenomenon is known as the fundamental attribution error (Festinger, 1957). So in the case of an accident, people are more likely to assign blame to someone else, thereby assuring themselves they will be able to avoid similar occurrences in the future.

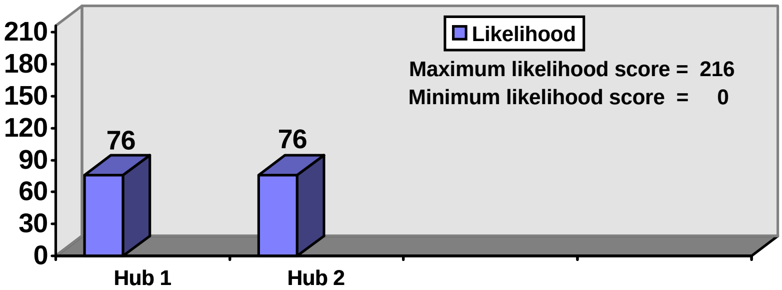
The questionnaire also produced an overall risk perception score for both *perceived hazardousness* and *perceived likelihood*, with a minimum score of zero representing no perception of risk and a maximum score of 216 representing an extremely high perception of risk. Mean scores for *perceived hazardousness* presented in figure 7 show that there is no significant difference between hubs 1 and 2.

FIGURE 7
Perceived hazardousness rating



Mean scores for *perceived likelihood* presented in figure 8 also show that there is no significant difference between hubs 1 and 2.

FIGURE 8
Perceived likelihood rating



INDICATE is designed to minimise the risk of air safety occurrences and it is expected that following the six-month trial period, a redistribution of the hazard rating scale will reveal a significant reduction in the mean *perceived hazardousness* and *perceived likelihood* scores of airline staff in hub 1, while mean scores for hub 2 should show little change.

6. CONCLUSION

Airline operators within the aviation industry undergo constant change. Expansion may take the form of new additions to existing aircraft fleet, recruitment of new staff, or the opening of new passenger routes. It is important for operators to proactively monitor how these changes may affect the current status of system safety. Current attempts to proactively monitor potential latent failures may be misplaced, due to their unforeseeable nature and the crucial role that defences play in preventing accidents. INDICATE is offered as a new method which provides a formal means for the airline industry to identify current safety deficiencies and bring them to the attention of BASI.

It is expected that INDICATE may provide a number of benefits for an airline:

- encourage better communication between management and employees about safety;

- reveal critical areas for development of procedures or training, and for priority inspections;
- provide a framework for feedback as to the efficacy of assumptions made about hardware or operational procedures;
- provide a baseline for management decisions regarding safety issues; and
- provide a cost-effective safety management tool.

INDICATE also encourages airlines to report safety problems more consistently. In Australia it is a legal requirement to report air safety incidents via an Aviation Safety Incident Report (ASIR). However, despite this mandatory requirement, there is a recognised problem of under-reporting, which in part stems from a lack of awareness about what should be reported.

While the implementation of INDICATE is only in its infancy, the results from the intervention phase of this study are encouraging. The response from regional airline staff participating in this trial has been positive and software is currently being developed by BASI to better manage the information produced from this program. A formal evaluation of INDICATE is yet to be completed, and further results from this trial will be published in BASI's *Asia-Pacific AIR SAFETY* magazine in early 1997.

Based on the results to date, it is expected that INDICATE will contribute to improving the quality of system safety within the Australian airline industry. Proactively identifying safety deficiencies before they have a damaging effect will ultimately improve airline safety performance and encourage 'best practice'.

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INDICATE METHODOLOGY

Timeline

	June 96	July 96	Six month trial	Dec. 96	Jan. 97
Hub 1 Intervention Group	Pre-intervention measures * Risk perception * Safety climate	INDICATE program	→	Post-intervention measures *Risk perception *Safety climate	Evaluation
Hub 2 Control Group	Pre-intervention measures * Risk perception *Safety climate	No intervention	→	Post-intervention measures *Risk perception *Safety climate	Evaluation